THE

GRAND PRIX CAR

by

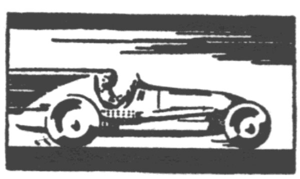
LAURENCE POMEROY

F.R.S.A., M.S.A.E.

Illustrated by

L. C. CRESSWELL

VOLUME ONE



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FOREWORD TO VOLUME ONE

THE work now presented succeeds THE GRAND PRIX CAR 1906-39 which was based upon a series of articles in *The Motor*. These were called " Milestones of Speed " and they appeared during the war-time years, the first, dealing with the 1908 Itala, appearing on 5th June, 1940, and the last, describing the 1939 3-litre Mercedes-Benz, being printed on 27th December, 1947. In the ensuing twelve months the author wrote additional matter, consisting of a survey of motor racing up until 1939 and a technical review of progress in the same period. Thus, as published in 1949, the GRAND PRIX CAR 1906-39 consisted of Part One, Grand Prix Racing ; Part Two, Examples of the Grand Prix Car ; and Part Three, Analysis and Synthesis. With appendices, there was a total of some 420 text pages.

At the time of publication, the later cars described were not remote in time and for most people the words " Grand Prix Car " summoned an image of a 3-litre Mercedes-Benz or Auto-Union. In other words, the information contained in the work was virtually contemporary. The first printing sold out during the two years 1949-50 and when the reissue of the volume had to be considered, it was obviously desirable to bring information about Grand Prix racing and Grand Prix cars up to date.

A logical stage for making a review was the end of 1953, when Formula 1, which was initiated in 1947, expired. But it eventually became obvious that the additional information available would result in a single volume of inordinate size and cost, and it was therefore decided to split the work into two volumes, of which this book is the first.

As a consequence, Volume One contains a history of racing up till 1939 and detailed descriptions of the principal racing cars which were built up to that time. It is not simply a reprint of the same matter contained in THE GRAND PRIX CAR 1906-39, for in both sections there is, as a result of the researches made in the past five years, a considerable amount of new information.

In this connection the author would like to take this opportunity of paying particular tribute to Monsieur Henri Petiet, who has provided a wealth of data concerning motor racing in the pre-1914 period ; to Mr. C. Posthumus, who has cleared up a number of obscure passages in the 1920-30 era, and also to Messrs. George Monkhouse, Harry Knox and P. S. De Beaumont, who contributed special information on various subjects.

The Fiat Motor Company and Dr. Giacosa have given full co-operation in providing new information and drawings regarding Fiat racing cars and Jules Goux, a some-time member of the Peugeot racing team, has made it possible accurately to assess the influence of 1908-10 small racing cars on subsequent Grand Prix cars.

It is intended that Volume Two shall provide a summary of racing in the 1947-53 period ; a description of the principal cars which appeared therein ; and the story of the technical evolution of the Grand Prix car from the earliest times up to the end of 1953. It is hoped, therefore, that the two volumes together will make it possible to study the complete chain of events in Grand Prix racing during the first half of the twentieth century.

In conclusion, the author would like to thank the many correspondents who have so generously given their time in suggesting improvements upon, and corrections to the text of the original work. Mr. R. Shepherd has been particularly helpful and although it is almost impossible entirely to avoid inaccuracies and omissions in a book of this magnitude, it is hoped that there are relatively few textual or statistical errors now remaining. Attention is, however, drawn to a note below on some comments and corrections which are relevant to this volume.

The author would like to renew his thanks to the Directors of Temple Press Limited, for their permission to engage in the additional work involved in the preparation of this book in its new form.

LAURENCE POMEROY, F.R.S.A., M.S.A.E.

London
November, 1953.

Comments and Corrections

Some corrected speeds were worked out after the text of Volume One had been printed, but fortunately before the Appendix giving the principal race results had gone to press. The speeds quoted in the latter should therefore be taken as definitive, and where discrepancies exist between the final tables and the earlier text, the former are marked with an asterisk. The races in error are : 1906 Ardennes ; European G.P. 1926 ; French G.P. 1913, 1914 and 1923 ; German G.P. 1934; Italian G.P. 1935 ; Monaco 1930; and Swiss G.P. 1937. Some textual corrections should also be noted as follows :

A. The stroke of the 1903 Mors car was 175 mm. and not 170 mm. as stated in the table on page 19.

B. The introduction of a live rear axle by Panhard was delayed until 1904 (not 1902 as stated on page 20) and in 1904 Clement Bayard also discarded chain drive, which they did not use in the Grand Prix of 1906.

C. As stated on page 23, the 1906 Grand Prix was run anti-clockwise ; not clockwise as inadvertently written on page 27.

D. In the 1908 Grand Prix the performance of the Renault was slightly better than stated on page 27. The car driven by Dimitri rose from eleventh place on the eighth lap to tenth on the ninth lap and eighth on the tenth and last lap. The Mercedes and Mors cars had H.T. ignition.

E. To clarify the poorly punctuated sentence on page 32, it should be made clear that entrants for the 3-litre race organised by the A.C.F. in 1912 had a choice of a Stroke : Bore ratio lying between 1 : 1 and 2 : 1.

F. In the 1916 Indianapolis race a fourth Peugeot started, retiring on the sixty-ninth lap. (Page 40.)

G. In the 1919 Indianapolis race the Peugeot driven by Goux finished third. (Page 43.)

H. In the 1921 Indianapolis race the Duesenbergs finished second, third, sixth and eighth, with only three retirements. (Page 45.)

I. In the I924 Indianapolis race the Mercedes driven by Werner finished eleventh. Lautenschlager ran subsequently in the 1924 Targa Florio in which he finished second in the 2-litre class and tenth in General Classification. (Page 51.)

J. In the middle of the right-hand column of page 125 the classification " Ignition " should read " Transmission ".

K. The 1913 Peugeot S : B ratio was 2.0 : 1. (Page 135.)

L. On page 146 the Crank Shaft specification should read " 4 piece built up ".

M. The 1927 Delage had a piston area of 30.4 sq. in. and developed 5.6 h.p./sq. in. (Page 180.)

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Part One

GRAND PRIX RACING

A Summary of Results

" Sunt quos curricula pulverem Olympictan
Collegisse iuvat, metaque fervidis
Evitata rotis palmaque nobilis
Terrarum dominos evehit ad deos ; "

HORACE.

" The firm which is building the high speed engine is adding to its knowledge of the durability of materials and of the effect of detail alterations at a rate which is incredible to those without similar experience."

L. H. POMEROY.

" Man is a noble animal, splendid in ashes and pompous in the grave, nor omitting ceremonies of bravery in the infamy of his nature."

SIR THOMAS BROWNE.

"The Führer has spoken. The 1934 G.P. formula shall and must be a measuring stick for German knowledge and German ability. So one thing leads to the other ; first the Führer's overpowering energy, then the formula, a great international problem to which Europe's best devote themselves, and finally action in the design and construction of new racing cars."

MANNSCHAFT UND MEISTERSCHAFT

CHAPTER ONE

Incentives and Restrictions

THE purpose of this work is to narrate the technical progress of the automobile as exemplified by Grand Prix racing cars, and this development cannot be properly understood without reference to the conditions imposed upon the designer by external forces.

Five principal factors have combined in the maintenance of motor racing over the past fifty years. They are the challenge to personal courage, the appeal of pageantry, the desire to use extreme competitive conditions as a forcing ground for technical improvements, the opportunity to advertise by demonstration that the products of one Company were superior to all rivals, and last, but by no means least, the means of providing political propaganda to prove the engineering supremacy of one particular nation and the implied supremacy of that nation in all walks of life.

These widely differing incentives have been largely co-existent but their relative order of importance has constantly changed. It is probable that the earliest races were based mainly on personal competition between various drivers and this element has persisted throughout the years becoming, however, more and more a feature of minor races supported by amateurs. In the Grandes Epreuves the accent quickly shifted firstly to a struggle between makes of cars and then, quite early on, to the theme of national rivalry.

In 1899 Mr. James Gordon Bennett offered the Automobile Club de France a trophy to be competed for by the automobile clubs of the various countries, each country to enter one, two or three cars, each of which had to be entirely constructed, including component parts, in the country which the cars represented. The total distance specified was between 342 and 404 miles.

The first Gordon Bennett race was held in 1900 with entries from France and the U.S.A., and may be considered the precursor of Grand Prix racing. By 1905, after two consecutive French wins, the Automobile Club de France considered that the regulations imposed an unfair handicap upon their own constructors, for France was at this time much the largest producer of cars, both in respect of total quantity and number of manufacturers, and the latter thought the limitation of three cars per nation stipulated by Gordon Bennett to be intolerable. Hence, in 1906 the A.C.F. organised the first of the Grand Prix races with which this volume is concerned. Entries at £200 per car were confined to manufacturers, but there was no limit to the number of makers from any given country who could participate and no restrictions concerning the nationality of component parts. The first Grand Prix race was nevertheless an almost undisguised effort to sustain French supremacy and was thus a logical continuation of the Gordon Bennett evaluation of motor racing victories in relation to country of origin. Later the overriding motives were those of technical development and advertising for the marque, and trade and politics apart, motor racing gave invaluable assistance in improving the breed of the normal motor car both in the " early days " of 1906-14 and for the first few years after the 1914-18 war.

For a few years after 1924 engineers felt, to some extent rightly, that the design of the racing car had become so specialised in conception, so costly in execution, that

it could not be justified in relation to the ordinary motor car. Simultaneously the offer of motoring to the masses throughout the world reduced the commercial value of a win in racing, for the potential market was no longer composed mainly of well-to-do men of the world but of those middle people of moderate means who had small knowledge of, and less interest in, motoring sport.

Over a period of nearly ten years we therefore witness a decline in Grand Prix racing, followed by an extraordinary revival in which first Fascist Italy and, subsequently, the Germany of the Third Reich used the spectacle of motor racing to excite emotions of superiority in the breasts of their own nationals, and to further the prestige of their general engineering industry in the minds of the world at large.

It will be observed that the pendulum swings from nationalism to individualism and back, and it was in this last period between 1934 and 1939 when companies like Auto-Union and Mercedes-Benz were encouraged by the German Führer and Reich Chancellor to spend hundreds of thousands of pounds per annum in motor racing that we see the most fantastic progress in power and speed.

Apart from these indirect influences on the design of racing cars there has been, as before mentioned, a direct control on Grand Prix cars in the shape of internationally agreed regulations, for only in the years 1929-33 has it been possible to race cars of any size or type. Thus it is essential to interpret the technical history of the Grand Prix car in relation to the regulations with which it has had to conform. A summary of these is, therefore, set out :-

1906 Maximum weight 1,000 Kg. (2,204 lb.).

1907 Fuel limited to 30 litres per 100 kilometres (9.4 m.p.g.).

1908 Maximum piston area 117 sq. in. Minimum weight 1,150 Kg. (2,534 lb.).

1912 Maximum width of car not to exceed 175 centimetres (69 ins.).

1913 Fuel limited to 20 litres per 100 kilometres (14.2 m.p.g.), contained in a bolster-type rear tank to standard dimensions, streamlined tails behind this tank being forbidden. Minimum weight without fuel 800 Kg. (1,760 lb.).

Maximum weight 1,100 Kg. (2,425 lb.).

1914 Maximum engine capacity 4.5 litres, superchargers and doped fuel forbidden, weight limits as 1913.

1921 Maximum capacity three litres. Minimum weight empty 800 Kg. (1,763 lb.).

1922, 1923, 1924 Maximum engine capacity 2.0 litres.
Minimum weight empty 650 Kg. (1,433 lb.).

End of tail not more than 150 centimetres behind rear wheel centre.

Note.-In all the foregoing years it was obligatory to carry two occupants with aggregate weight not less than 120 Kg. (264 lb.) or equivalent weight in ballast.

1925 Maximum engine capacity 2.0 litres.
Minimum weight empty 650 Kg. (1,430 lb.).
Two-seater bodies. Minimum width 80 centimetres (31.5 ins.).. Driver only for this and all following years.

1926 Maximum cylinder capacity 1.5 litres.
Minimum weight 600 Kg. (1,322 lb.).
Two-seater bodies. Minimum width 80 centimetres.

1927 Maximum engine capacity 1.5 litres.
Minimum weight 700 Kg. (1,543 lb.).
One or two-seater body.
Minimum width 85 centimetres (33.5 ins.).

1928 Minimum weight 550 Kg. (1,212 lb.). Maximum weight 750 Kg. (1,653 lb.). Minimum distance 600 kilometres. (Only used for Italian Grand Prix.)

1929 Minimum weight 900 Kg. (1,980 lb.). Minimum body width 100 cm. (39.3 ins.). Pump fuel. Maximum consumption fuel plus oil 14 Kg. (30.8 lb.) per 100 kilometres (62.1 miles) (14.5 m.p.g. approx.). (Only used for French and Spanish Grands Prix.)

1930 As 1929 but 30 per cent added Benzo1 permitted. (Only used for French and Belgian Grands Prix.)

1931 Minimum duration 10 hours. Any type of car.

1932 As 1931. Duration 5 to 10 hours.

1933 As 1931-32. Duration 500 kilometres.

1934, 1935, 1936, 1937 Maximum weight 750 Kgs. (1,653 lb.). Minimum body width 85 cm. (33½ in.).

1938, 1939 Sliding scale relationship between weight and engine capacity, the latter limited to 3 litres supercharged, 4½ litres unsupercharged. Minimum weight for cars with engines of either of these sizes 850 Kgs. (1,873 lb.).

(The A.I.A.C.R. definition of weight is for a car with oil and four wheels, without water, fuel, tyres, tools, spares and spare wheel, except for the five years 1934-39 during which time oil and wheels were also excluded.)

It will be observed that the favoured rule has been a limitation on cylinder capacity, which naturally had the effect of forcing the pace in the development of small high-output engines. Considerable technical advances have, however, taken place in the periods when restriction by weight was imposed. Despite the many theoretical arguments in favour of a fuel consumption rating, proposals on these lines have normally been out-voted or ignored.

It is interesting to observe that entrants have never welcomed complete freedom in the construction of racing cars. There has perhaps been a feeling that such liberty produces too many variables and makes an investment into a given design an unduly hazardous proposition.

To conclude this chapter it may not be out of place to observe that whilst motor racing may to some extent have influenced national affairs, national characteristics have exercised equally a profound influence on motor racing. In Great Britain the ideal of the amateur has always held a high place in every sport. Racing in this country has, therefore, tended towards a competition between moneyed young men, events have been organised to agree with their needs and International Racing has received little support. Austin and Weigel ran in 1908, Vauxhall in 1914, Aston Martin in 1922; and Alvis entered in 1926 and 1927, but only Sunbeam consistently supported Grand Prix racing from this country, with teams of three cars entered in 1912, ‘13, ‘14, ‘21, ‘22, ‘23, ‘24 and ‘25. In other words, support for Grand

Prix racing so far as England is concerned has rested with the Sunbeam Company with occasional intervention from others.

By contrast, Grand Prix racing has always been regarded by Continental nations as one of the highest exercises of professional skill in design, construction and driving. Large numbers of companies have exerted immense efforts and spent vast sums, drivers have been retained at high fees, and have driven under strict team orders - not, it may be mentioned, always obeyed.

From the public viewpoint Grand Prix racing has been perhaps the most popular form of sport in Europe. The names of the great drivers and the merits of their differing styles have been a source of discussion for the common man, and in the peak years immediately before World War II crowds of over a quarter of a million persons were not exceptional. Any effort to estimate the importance of Grand Prix racing must, in consequence, take account of the violent contrast in outlook existing on the opposite sides of the English channel, but this is an aspect of racing with which we are not immediately concerned.

To evaluate the merits of various designs it is, however, essential to have some knowledge of their performance on the road. The first part of this book is, therefore, devoted to a brief and purely factual account of Grand Prix racing which may perhaps serve as a basis for a full scale work on this theme from a writer skilled in the art of dramatic narrative.

CHAPTER TWO

Before 1906

THE first real motor race was over 732 miles from Paris to Bordeaux and back, and was won by Levassor, who drove for 48 hours 48 minutes on a Panhard and averaged 15 m.p.h. The date was June 11th to 13th 1895.

The history of ensuing events is particularly well documented in *A Record of Motor Racing,** by Gerald Rose and, thus, in this volume no more than a résumé of his work need be given This shows that in the first five years average speeds rose steeply, the highest winning speeds in any given year between 1895 and 1900 being :–

Year	*M.P.H.*	*Winning Car*	*Route or Circuit*	*Total Mileage*
1895	15	Panhard	Paris-Bordeaux-Paris	732
1896	15.1	Panhard	Paris-Marseilles-Paris	1,062
1897	25.2	Panhard	Paris-Trouville	107.7
1898	26.9	Panhard	Paris-Amsterdam-Paris	889
1899	37	Mors	Bordeaux-Biarritz	163
1900	43.8	Panhard	Circuit Sud Ouest	209
1900	40.2	Mors	Paris-Toulouse	837

From the first year of the twentieth century forward we can also reliably estimate the maximum speed of road racing cars by consulting the record book Cars built especially for the flying kilometre record were not made before 1905, and before 1902 the highest speed achieved was with steam or electric cars, but within the three years mentioned we observe the following performances with petrol-driven cars :–

M.P.H.	*Drivers*	*Car*	*Cyl.*	*Date*	*Time*	*Place*	*A.I.*
76.09	W. K. Vanderbilt	Mors	4	5/8/02	29.4	Ablis-St. Arnoult	12.R
76.60	H. Fournier	Mors	4	5/11/02	29.2	Dourdan	12.R
77.14	Augieres	Mors	4	17/l l/02	29.0	Dourdan	12.R
83.47	Rigolly	Gobron-Brilié	4	17/ 7/03	26.8	Ostend	12.R
84.73	Duray	Gobron-Brillié	4	5/11/03	26.4	Dourdan	12.R
94.78	Rigolly	Gobron-Brillié	4	31/ 3/04	23.6	Nice	12.R
97.26	P. De Caters	Mercedes	4	-/ 5/04	23.0	Nieuport-Ostend	12.R
103.56	Rigolly	Gobron-Brillié	4	21/ 7/04	21.6	Nieuport-Ostend	12.R
104.53	P. Baras	Darracq	4	13/11/04	21.4	Nieupoti-Ostend	12.R

* Published by MOTOR RACING PUBLICATIONS LTD. 42s.

Translating into winning average speeds on the road we find that some cars were capable of sustaining over 70 m.p.h. for long distances, the speed increments in the five years 1900-05 being as follows :–

Year	*M.P.H.*	*Winning Car*	*Route or Circuit*	*Total Mileage*
1901	***53***	Mors	Paris-Bordeaux	327
1902	54.5	Panhard	Ardennes Circuit	318
1903	65.3	Mors	Paris-Bordeaux (Madrid)	342
1904	72	Fiat	Florio Circuit (Bologna)	231
1905	65.1	Itala	Florio Circuit (Bologna)	311

Yet another change came over the racing scene in the first five years of the twentieth century. In the late 90's Panhard had dominated the scene, the number of victories each year before 1900 being :-

1895 Panhard (1).
1896 Panhard (1).
1897 De Dion (Stea) .(2), Panhard (1).
1898 Panhard (4), Bollée (1).
1899 Panhard (4), Peugeot (l), Mors (1).

In sum, out of sixteen races, Panhard won 11, De Dion 2, and Peugeot, Bollée and Mors one race each.

From 1900 onwards the table is :-

1900 Panhard (4), Mors (2).
1901 Panhard (l), Mercedes (l), Mors (2).
1902 Panhard (3), Napier (1).
1903 Mors (l), Panhard (l), Mercedes (1).
1904 Richard Brasier (l), Panhard (I), Fiat (1).
1905 Richard Brasier (l), Darracq (l), Itala (1).

So in twenty-two races Panhard won 9, Mors 5, R-Brasier and Mercedes 2 races each, and Napier, Fiat, Itala and Darracq one race each. It is of particular interest that although Panhards retained numerical supremacy in the 1900-05 period they secured only two firsts in the three seasons 1903-05, in which years no fewer than seven other makes achieved victory.

The decline and fall of Panhard was due to their inability to keep in the forefront of technical progress. The earliest cars used for racing, as we have previously observed, were normal vehicles as sold later to the public. The Panhard is fully described in *Motor Vehicles and Motors,* by W. Worby Beaumont, as are a number of other pre-1900 vehicles. Many of these (including Panhard) used engines built under licence from Daimler and thus in a sense emanating from what was to become the Mercedes and later the Mercedes-Benz factory.

A cross section of the 1899 engine is typical of all these earlier power units ; it has a laterally located exhaust valve and an overhead automatically operated inlet valve. A passage is drilled from a chamber beneath the inlet valve into a burner containing a platinum tube, this forming a primitive ignition arrangement on these early types. The maximum engine speed was limited by a governor giving interrupter action on the exhaust valves, and this normally maintained the engine at 700 r.p.m. However, a lever on the dashboard of the car could be moved so as to fix the engine speed at any required r.p.m., and an accelerator control made it possible to frustrate the governor entirely, the engine speed then increasing to some 1,200 r.p.m.

A drawing of the car shows an outrigged rear seat, but this was supplementary and not carried when the car was racing (Plate I).

Another incidental feature of interest is the low mounting of the cooler which consisted of a 55 ft. pipe of ½ in. diameter carrying thin light alloy fins. Mounting at the rear was presumably dictated by considerations of space. This was the type of Panhard used by De Knyff to win the Paris-Bordeaux race, and by Charron in the Paris-Amsterdam-Paris race at average speeds of 22.1 and 26.9 m.p.h. respectively.

The first developments in engine design were mainly confined to enlargements of capacity. Output, measured either per litre or by square inch of piston area, changed very little for the first four years, during which time, however, swept volume increased from 1.2 litres to 4.4 litres. By 1901, however, Mors were using 10 litre engines and Panhard replied in 1902 with the famous " 70 " of 13.7 litres. Engine design had in fact began to get under way and progress can perhaps best be analysed in a table :–

Year	*Make*	*Bore and Stroke M/M*	*Cyl. No.*	*Capacity Litres*	*B.H.P.*	*H.P./Litre*	*H.P./Sq. Ins*
1895	Panhard	80 x 120	2	1.2	4	3.3	0.26
1896	Panhard	80 x 120	4	2.4	8	3.3	0.26
1899	Panhard	90 x 130	4	3.3	12	3.65	0.32
1899	Panhard	100 x 140	4	4.4	16	3.65	0.33
1900	Panhard	110 x 140	4	5.3	24	4.5	0.40
1901	Mors	130 x 190	4	10.1	60	6	0.73
1902	Panhard	160 x 170	4	13.7	70	5.1	0.56
1903	Mors	145 x 170	4	11.2	70	6.25	0.70
1904	Brasier	150 x 140	4	9.9	80	8.1	0.73

It may also be interesting to consider certain figures for engine size and output just prior to the Grand Prix era. Manufacturers in the early days of motoring quite freely quoted their h.p. figures and there is reason to believe that they were not unduly optimistic in their claims. Accurate published statistics are hard to come by so it is, therefore, interesting to look up the trials made by the A.C.F. in 1906, when they were searching for some rating rule. It may not be generally known that the British

R.A.C. formula and the corresponding S.A.E. formula in the U.S.A. were based on these trials in which ninety-six engines were bench-tested by an independent authority. In the published results these engines are referred to by number only, but by looking through the cylinder dimensions it is possible to identify, with some reasonable probability, a number of relevant types. These can be set out in a table thus :–

Make	*Year*	*No. of Cyls.*	*Cyl. Dimensions M/M*	*Cyl. Capacity Litres*	*B.H.P.*	*R.P.M.*	*Ft./ Min.*	*M.E.P.*	*H.P./ Litre*	*H.P./Sq. Ins.*
Panhard	1903	4	160 x 170	13.7	90	1,260	1,400	69.5	6.55	0.74
Mors	1904	4	170 x 150	13.6	100	1,200	1,200	80	7.35	0.72
Mercedes	1904	4	165 x 140	12	105	1,380	1,270	82.5	8.75	0.80
Fiat	1905	4	180 x 160	16.2	120	1,100	1,040	88.0	7.4	0.67
Richard Brasier	1905	4	160 x 140	11.3	101	1,350	1,240	86.5	9.1	0.84

The high m.e.p. of the Fiat is particularly noteworthy and it is obvious that breathing of engines was being materially improved.

So far as chassis design is concerned a major development was the change (*circa* 1897) from tiller to wheel steering, Panhard adopting the latter in 1898, in which year also this Company used aluminium for a number of components, particularly carburetter and gearbox.

In 1900 the honeycomb radiator had made its first appearance but chassis were made from wood reinforced with metal plates. In the next year or two, however, the all-steel channel frame came to be common and 1902 is notable for the introduction by Mors of dampers to the springs.

The Gordon Bennett rules prescribed a maximum weight of 1,000 kg. (2,204 lb.), and in view of the size of the engines that were being used it was remarkable that a complete car could be held to this figure. As it'was, margins of mechanical safety were sometimes cut too fine although great ingenuity was shown in various methods of genuine weight saving. For example, the separate cylinders of the Panhard engine had copper water jackets only 1 mm. thick. This engine weighed under 700 lb. and gave 90 h.p. on the brake. The specific weight, therefore, was 7.8 lb. : B.H.P. The majority of these early cars had low tension ignition and from 1902 onwards the automatically operated inlet valve gave way to the mechanical type although it was still not infrequent for the camshafts themselves to be exposed. Daimler, with their Mercedes model, pioneered the use of the throttle valve in 1901, the speed of the previous cars having been controlled by various governing arrangements, in some cases hit and miss on the ignition and in others by changing the lift of valves. In 1902 almost all the larger cars retained chain drive, but Renault and Panhard had already changed to the live rear axle.

By 1905 France, after a decade of supremacy, was on the verge of being challenged, and not only do we see a shaft-driven Itala amongst the winning makes, but also Fiat, the latter with a remarkable car with 16.2 litre engine capacity, which had push-rod operated valves mounted in the head at an included angle of 90 degrees. Only ill-luck prevented the victory of these cars in two major races.

The last of the Gordon Bennett series of races was held in 1905 with competition between two Richard Brasiers and one De Dietrich car for France, three Fiats for Italy, three Mercedes for Germany, two Wolseleys and one Napier for England, two Pope Toledos and one Locomobile for the U.S.A.

There were very wide variations in the type and size of car. Lancia on a Fiat proved to be easily the fastest driver, putting in a record lap at 52.6 m.p.h. on a mountainous circuit 85 miles long. Later, he had radiator trouble and the race was eventually won by Théry on a Richard Brasier, who had a comfortable margin over Nazzaro, whose Fiat was runner-up.

The speed of these immediately pre-Grand Prix cars is indicated by the speed made by Lancia (again driving a Fiat) in the Vanderbilt cup race held in the United States on October 14th, 1905. Although again he failed to finish-this time due to an accident-he put in a lap at 72 m.p.h. However, it will perhaps be best (in virtue of its Gordon Bennett win) to take the Richard Brasier as a typical example of design.

In 1905 we find it had a capacity of 11.3 litres and developed slightly over 100 h.p. Two valves per cylinder were mechanically operated and the leather cone clutch drove to a three-speed gearbox with a countershaft and chain drive. Cooling was by pump through a tubular finned radiator and a channel pressing was used for the frame. This car, of course, had brakes on the rear only, but was a thoroughly soundly constructed vehicle which ran with considerable speed and regularity. The weight was only 994 kg.

The 1905 Hotchkiss is also worthy of mention, as on this car a live rear axle was located by semi-elliptic springs which were also used to drive the car-an arrangement copied by Hola and Peugeot, and which has since been widely followed on racing cars and has become almost universal on production models.

In sum, before the first Grand Prix race was held, racing cars had developed to a high standard of effectiveness, if not perhaps of efficiency in the terms of power for a given size of engine. What is more, with light axles the ratio of sprung to unsprung weight was good despite the low all-up weight. Hence, the road holding, particularly on those cars fitted with shock absorbers, was very much better than many people have imagined, and this standard of control was achieved without using excessively stiff springs, so that the driver had a more comfortable ride than he did on later models.

The striking increases in speed in the period 1900-05 had, however, been realised almost entirely by enlarging engine size. The first Grand Prix races showed little change in this respect and, from a technical point of view, the events of 1906, '07, and '08, may be considered a continuation of the Gordon Bennett era.

Perhaps with this in mind the Automobile Club de France have retrospectively added eight pre-1906 races to their list of French Grands Prix so that on this reckoning the first event actually to be organised with this title now counts as " Le IXeme Grand Prix de 1'A.C.F." The preceding events in this score are : Paris-Bordeaux-Paris, 1895 ; Paris-Marseilles-Paris, 1896 ;. Paris-Amsterdam, 1898 ; Tour de France, 1899 ; Paris-Toulouse-Paris, 1900 ; Paris-Berlin, 1901 ; Paris-Vienna, 1902 ; Paris-Madrid (stopped at Bordeaux), 1903.

CHAPTER THREE

The Age of Monsters

RACING STATISTICS 1906-08

Date	*Event*	Course	*Driver*	*Car*	*Winning Speed m.p.h.*	*Lap Speed (Rec'd *)*
26/6/06	French G.P.	Le Mans	Szisz	Renault	63	
26/6/06	,,	,,	P. Baras	R. Brasier	—	73.3*
13/8/06	Ardennes Prize	Ardennes Circuit	L. Duray	De Dietrich	65.5	—
13/8/06	,, ,,	,, ,,	L. Wagner	Darracq	—	70*
14/6/07	Kaiser Prize	Taunus Mountains	F. Nazzaro	Fiat	52.5	—
2/7/07	French G.P.	Dieppe	F. Nazzaro	Fiat	70.5	—
2/7/07	,,	,,	A. Duray	De Dietrich	—	75.4*
25/7/07	Ardennes Prize (8-litre class)	Ardennes Circuit	J. T. C. MooreBrabazon	Minerva	59.5	—
25/7/07	,, I,	,, ,,	A. Lee Guinness	Minerva	—	67
25/7/07	,, ,, (G.P. Class)	,, ,,	Baron de Caters	Mercedes	57.3	—
25/7/07	,, ,, (G.P. Class)	,, ,,	C. Jenatzy	Mercedes	—	66.6
7/7/08	French G.P.	Dieppe	C. Lautenschlager	Mercedes	69	—
7/7/08	,,	,,	0. Salzer	Mercedes	—	78.5*
6/9/08	Coppa Florio	Bologna	F. Nazzaro	Fiat	74.1	—
6/9/08	,,	,,	V. Lancia	Fiat	—	*82.3**

THE 1906 Grand Prix, held on June 26th and 27th, was not only technically but also politically a continuation of the Gordon Bennett series. The organisers, the Automobile Club de France, were activated largely by the desire to have a French win, and by opening the race to an unlimited number of cars from each country they did much to ensure one as France in those days was the dominant producer of automobiles.

The formula limiting the design of the cars was the same as that imposed previously at Gordon Bennett events, a maximum weight of 1,000 Kg. (2,204 lb.) with a supplement of 7 Kg. to cover a magneto or dynamo driven from the engine and used for ignition. A change was, however, made in respect of the number of helpers who were permitted to work on the car. In the Gordon Bennett races no limit was placed, but for the Grand Prix event it was stipulated that all repairs, including tyre changes, must be effected by driver and mechanic working alone.

The course was a triangular circuit near Le Mans, 65 miles in length, and this had to be covered six times on two consecutive days, an interesting feature being the construction of a wooden by-pass road to avoid St. Calais. This scheme was adopted as an alternative to the arrangement in the Gordon Bennett series in which competitors had been forced to slow down and observe a no passing rule when traversing town limits.

It is interesting that in the original regulations and maps of the course the cars were to run clockwise, but in the end it was decided to retain the tradition dating back to the days of the Roman chariot race, and to run anti-clockwise. The grandstands were placed on the inside of the course and the replenishment depot opposite-an arrangement which enabled the cars to draw up at their " pits " (which were in fact areas marked out at road level) without leaving the right-hand side of the road but which made access to the stands during the race somewhat difficult.

The entries comprised ten teams from French constructors, two from Italy and one from Germany, and with three exceptions every maker entered three cars. There were, therefore, twenty-six French cars competing against six Italian and three German.

Technically the vehicles showed little change from those which had been running for the past two or three years. The Gobron-Brillié was, in fact, of 1903 construction, whilst the Brasiers were very similar to the winning Gordon Bennett cars of 1904 and 1905, but slightly lowered. All had four-cylinder engines, and all serious competitors had an engine capacity of 12 litres or more, Panhard having the largest with 18 litres.

There was a marked division of opinion in the matter of transmission. R-Brasier, Cl. Bayard, F.I.A.T., Gobron-Brillié and Mercedes had chain drive, the rest propeller shaft and live axle. Magnetos were used by everyone for ignition purposes, but only Gobron, Panhard and Renault used high tension ignition ; the rest had low tension systems with contact points inside the cylinder:

The one technical novelty of the race was the use by the Brasier, F.I.A.T., Itala and Renault teams of detachable rims. These were of considerable benefit under the new ruling which prohibited external assistance, an arrangement which had put a premium on a well-trained team who could slash off worn covers with knives and quickly force new tyres on to the rim. The 1906 rules restricted this work to tired drivers and mechanics, who necessarily lost a tremendous amount of time when replacements were needed.

The first Grand Prix of all started at 6 a.m., when Gabriel was despatched on one of the De Dietrich cars, carrying the number 1A, but actually it was number 2A, Lancia on a Fiat, who made history by crossing the line first as Gabriel stalled on the line ; car followed car at 90 second intervals until finally Teste got under way on a Panhard, number 10C, at 6.50 a.m. Fabry made the fastest start, his Itala being timed over the first standing kilometre in 43.4 secs., which equals 52.4 m.p.h., but Baras on a Richard Brasier was first on the opening lap at an average of 73.3 m.p.h. This speed proved to be the fastest recorded in the race, despite the standing start, but the great length of the circuit made the time lost when leaving the line a negligible factor.

Baras retained his position for a second circuit before dropping down to third on the third lap, fourth on the fourth lap, and thirteenth on the fifth lap, and also the sixth, which terminated the day's racing. A Hungarian driver in the Renault team, Szisz, made a slower start but a better finish, coming up from third on the first lap and

fourth on the second to first on the third, from which position he was not displaced during the remainder of the first day, at the end of which positions were :–

Car	*Driver*	*Total Time*	*Average Speed*
Renault	Szisz	5 hrs. 45 mins. 30.4 secs.	66.8 m.p.h.
ClCment Bayard	A. Clément	6 hrs. 11 mins. 40.6 secs.	62.2 m.p.h.
Fiat	F. Nazzaro	6 hrs. 26 mins. 53.0 secs.	59.6 m.p.h.

The position of the Cl. Bayard was notable, as its team had to bear the burden of fixed wheels, whereas both Renault and F.I.A.T. had the advantage of the detachable rims, which enabled driver and mechanic to fit an inflated tyre at the rate of two minutes per wheel.

The second day's start was not, as on the previous morning, in the order of numbers, but in the order of finishing the previous evening. Two extra mechanics were allowed to re-start the engine of each car, and Szisz immediately drove to his depot and spent twelve minutes re-fuelling and fitting new tyres. Clement got going inside five minutes, and Nazzaro went straight off into the race. It will thus be observed that the Cl. Bayard started only nineteen minutes behind the leader and F.I.A.T. twenty-nine minutes behind.

When Szisz finished his first lap, eleven cars were still waiting to be sent off, four being held on the starting line when he had completed his second lap. He was, in fact, so far ahead that he could take the whole of the race comparatively easily and still lead throughout the whole of the day. A De Dietrich, driven by Rougier, made the fastest lap at an average of 72.1 m.p.h., and as Clement made up a few minutes (in spite of his gain at the start), the F.I.A.T. and Cl. Bayard positions became reversed, and at the end of the second day, after 769.9 miles of racing, the results were :–

Car	*Driver*	*Final Time*	*Average Speed*
Renault	Szisz	12 hrs. 14 mins. .07 secs.	63 m.p.h.
Fiat	F. Nazzaro	12 hrs. 46 mins. 26 secs.	60.4 m.p.h.
Clément Bayard	A. Clément	12 hrs. 49 mins. 46t secs.	60.1 m.p.h.

Only eleven cars out of thirty-two starters finished this severe race, and although Fiat was second and fifth, the French could justly congratulate themselves on having seven finishers.

The winner ran an extremely regular race, and although on neither day did he feel it necessary to put up the quickest lap, he was the fastest car to be timed over a flying kilometre, reaching a speed of 92.2 m.p.h. Nazzaro was timed at 87.2 m.p.h.

Another race of importance in 1906 was held on the Ardennes Circuit on August 13th, run over 371 miles. Renault rested on their Grand Prix laurels, but De Dietrich, Darracq, Richard Brasier, Cl. Bayard and Mercedes all entered teams, a Darracq making the fastestrlap at 70 m.p.h., and a De Dietrich winning at 65.5 m.p.h., Duray being the driver.

The success of the 1906 Grand Prix had two consequences, to move the A.C.F. to an early decision to renew the event for 1907, and to spur the Germans into organising a race of comparable importance, but held under regulations more acceptable to German constructors. The result was a race for the Kaiser Prize on June 13th and 14th of 1907, followed by the French Grand Prix on July 2nd.

A circuit in the Taunus Mountains, 73 miles long, was chosen for the German event and the maximum capacity was limited to 8 litres, thus encouraging the normal production type of motor car, and specifically excluding the high-powered racer.

The support of manufacturers was almost overwhelming. An entry of ninety-two cars was received, and this meant that with competitors leaving at one-minute intervals the first man round would come round to the start when a number of cars were still awaiting despatch. To avoid this the race was run in two eliminating events on the 13th June, bringing the racing on the 14th June down to forty cars. Fiats were first in both the eliminating events, and also in the race itself, which was won by Nazzaro at 52.5 m.p.h., followed by a Pipe, two Opels and two more Fiats.

The French Grand Prix was run on a new course and under new regulations, limiting fuel consumption. A circuit was chosen near Dieppe, flat, triangular in shape and 47.74 miles round. It had to be covered ten times on one day.

Anti-clockwise rotation was again used and, reviving a practice established in the Gordon Bennett races, it was obligatory upon the entrants to paint their cars in recognised national colours, viz. English, green ; French, blue ; German, white ; U.S.A., white and red ; Belgian, yellow ; Italian, red ; Swiss, red and yellow. In the previous year manufacturers had been at liberty in this respect, and the winning French car had been painted red.

Eleven teams of cars entered under the French colours and one each representing Belgium, Italy, Germany, Great Britain, and the U.S.A. There was a total of thirty-eight starters, all of which had four cylinders except Dufaux, Porthos and Weigel cars, which used straight-eight engines.

The cars again showed little change compared with the previous year’s models ; in fact Renault, having sold their team of cars the previous year, constructed virtual replicas thereof. With other makers the similarity in engine dimension is an indication that the new regulations had brought little change in design.

Lancia started at 6 a.m., on a Fiat, the remaining cars followed at minute intervals, and the Renault-Fiat duel of the previous year was at once renewed, with De Dietrich intervening.

Wagner on a Fiat led for the first three laps at an average speed of 72.1 m.p.h., and was then forced to retire. Duray, on a De Dietrich then moved up from second position and held the lead at an average of 70.6 m.p.h., but after a record lap at 75.4 m.p.h. with two laps to go, with Nazzaro on a Fiat lying second and Szisz on a Renault third, Duray retired with a seized gearbox. The elimination of the De Dietrich raised both cars one place in the order, but the Italian had an unshakeable lead. The finishing order was :–

Car	*Driver*	*Final Time*	*Average Speed*
Fiat	F. Nazzaro	6 hrs. 46 mins. 33 sets.	70.5 m.p.h.
Renault	Szisz	6 hrs. 53 mins. 10.6 sets.	69.4 m.p.h.
Richard Brasier	Baras	7 hrs. 05 mins. 05.6 sets.	67.4 m.p.h.

The Fiat team put up an outstanding performance. Wagner was fastest on the first and second laps and Nazzaro on the sixth, seventh, ninth and tenth laps. But Jenatzy, on a Mercedes, was fastest on the fifth lap, this being one of the very few in

which he did not have trouble. Whether the spectators realised this as the omen it was may be doubted.

Seventeen cars, twelve of them French, finished out of thirty-seven starters, and, although losing first place, the French were by no means outclassed. It is indeed arguable that a mistake on the part of the Renault équipe had markedly affected the race, for Nazzaro finished with less than 2½ gallons of petrol, whilst Szisz finished with over 6½. On the other hand, Nazzaro with his greater speed consumed 95 per cent of his fuel allowance, which was certainly running things very fine indeed.

Two races over the Ardennes Circuit were run on July 25th and 27th and these proved highly significant from a technical point of view. On the first day, racing was confined to cars conforming with the under 8-litre Kaiser Prize regulations, and Minervas finished first, second and third, the winner, J. T. C. Moore-Brabazon (now Lord Brabazon of Tara), averaging 59.5 m.p.h., and another Englishman, A. Lee Guinness (now Sir Algernon Guinness), putting up the fastest lap at 67 m.p.h. Only a very small entry was received for the Grand Prix category, which was won by Baron de Caters on a Mercedes at 57.3 m.p.h., the fastest lap being made by Jenatzy, also on a Mercedes, who averaged 66.6 m.p.h., both less than the " small " car speeds. Even more interesting, A. Lee Guinness, who came in second, took 49 minutes 56 seconds to lap on his 13.6-litre Grand Prix Darracq, whereas he needed only 49 minutes 40 seconds on the 8-litre Minerva.

There had been a steady increase in engine capacity for some ten years, and at the time of the first two Grand Prix races, the fastest cars had engines of between 13- and l8-litres swept volume. The Ardennes Race indicated that this tendency towards huge engines had gone too far (a view strongly supported by the Germans) and led to the 1908 French Grand Prix being run for cars with a maximum piston area of 117 sq. in., the equivalent of a cylinder bore of 155 mm. for four-cylinder engines, or 127 mm. for six-cylinder types. The minimum weight was 1,150 Kg.

The entry list for the 1908 race shows a notable diminution of the French entry. Cars of this nationality maintained their majority position but comprised only eight teams compared to three from Gerrnany, two from Italy, two from Great Britain and one each from Belgium and U.S.A. Only two makers failed to put in a team of three, so that there were forty-eight cars entered, all having four cylinders, except Austin and Porthos, who used six-cylinder engines. All the entries were of entirely new design embodying features of considerable technical interest. Richard Brasier, Dietrich, Fiat, Itala, Mercedes and Mors retained low tension magnetos ; all the other entries employed high-tension ignition. The honeycomb radiator introduced on the first Mercedes of 1901 had now won almost complete acceptance, only Brasier and Mors using the gilled tube type and Renault a variation thereof. Four speeds were also preponderant, being used by all except Brasier, Germain, Mors, Porthos, Renault and Weigel. Opinion was divided in the matter of final drive. Chains were employed by Benz, Dietrich, Fiat, Germain, Mercedes, Mors, Motobloc, Panhard and Porthos, the case of Panhard being particularly interesting, in that it was a reversion from propeller shaft and live axle after five years of racing.

It was, however, in engine design that the major changes were made. Valves inclined at 45 degrees were used by Fiat, Dietrich, Benz, Clement Bayard and Weigel, the last two also having an overhead camshaft. A notable reduction in engine capacity was also to be observed, the largest car having less than 14-litres swept volume and the most popular size being 155 x 170 mm., giving a capacity of 12.83-litres.

A further point of considerable technical significance was to be found in the organisation of the race. The circuit was the same as on the previous year, but for the first time in racing history a replenishment area was marked out, and trenches or " pits " were dug at the side of the road in which spares, fuel and tyres were lodged. Fuel under pressure was supplied from large drums; quick lift jacks were employed, Mercedes even having pneumatic jacks available.

It will be recalled that the last-minute decision to run the 1906 Grand Prix on a clockwise circuit made it necessary to put the grandstands on the inside of the course, as the replenishment depots had to be on the right-hand and, in this case, outside of the course. The practical disadvantages of this arrangement are evident, and therefore in the following year both replenishment depots and grandstands were placed on the right-hand side of the course, making it essential for the former to be put below ground level in order that the spectators in the lower seats of the grandstand could retain their view of the passing cars.

In 1908 the replenishment area was for the first time set back from the main course so that the effective use of the road for racing was not diminished by a stationary car which was being worked upon. This also has, of course, been followed in subsequent prominent circuits such as Monza, Montlhéry, Nurburg, Rheims, and the like, although in subsequent races run anti-clockwise it has perhaps been more normal to put the replenishment area opposite the grandstand and to keep supplies at road level.

The race was a disaster for French, a triumph for German, cars. Renault were using a new type of detachable rim, which caused them great trouble, and at no time were they better than eleventh. Panhard never secured better than fifth place, Cl. Bayard at first were right out of the picture (ninth), and Motobloc were never higher than eleventh, leaving the only effective competition to come from Richard Brasier and De Dietrich. A car from the latter équipe reached sixth place on the second lap and then disappeared from effective competition, but at the end of the first lap the Brasiers of Bablot and Théry were second and third, Bablot being a bare nine seconds behind the leader. After this he ran into trouble but Théry held fourth place from the fourth to the ninth lap, at the end of which he was forced to retire having averaged 64.4 m.p.h. up to that point.

A Mercedes was first on the opening lap, and again put up a record from a standing start, the speed being 78.5 m.p.h. This car then broke down, putting first Nazzaro and then Wagner on Fiats into the lead on the second and third laps. They both retired on the fourth lap, having averaged 73.7 m.p.h. up to this time, which left Hemery in the lead on a Benz, with Mercedes (Lautenschlager) running second. These positions were reversed in the sixth lap, and unchanged thereafter, the final positions being :-

Car	*Driver*	*Total Time*	*Average Speed*
Mercedes	Lautenschlager	6 hrs. 55 mins. 43.8 secs.	69 m.p.h.
Benz	Hemery	7 hrs. 04 mins. 24 secs.	67.5 m.p.h.
Benz	Hanriot	7 hrs. 05 mins. 13 secs.	67.4 m.p.h.

The roads were not in such good condition as they had been the previous year, and even driving with the utmost care, the winner had to stop nine times for tyre

renewals. But Rigal, on a Cl. Bayard, stopped nineteen times, despite which fact he finished 4th and first of the French cars, averaging 63.6 m.p.h. It is established that Cl. Bayard was the fastest make in the race (*vide* page 262), which was remarkable for the fact that over twenty of the forty-eight entries exceeded 100 m.p.h. over a timed flying kilometre.

These figures represent a marked advance in technique, an advance further proved by the results in the Coppa Florio of 1908, held at Bologna in September. Fiat, De Dietrich, Itala, Mors, Cl. Bayard and Motobloc all entered teams of Grand Prix cars, and Fiat showed a remarkable supremacy, Nazzaro winning at 74.1 m.p.h; for 328 miles. Fastest time for the 32.8 mile circuit was achieved by Lancia on another Fiat at 82.3 m.p.h.

Politically, and from the French point of view, the results of the A.C.F. Grand Prix races had been by no means encouraging. In the first three races, run under regulations specifically beneficial to French manufacturers, they had only provided the winner once. Italy had won once and so had Germany. A legend has since grown that the Automobile Club de France abandoned the Grand Prix series in order to avoid further humiliation for French constructors, but this is not true. The International Commission met on October 19th, 1908, and decided to run a 1909 Grand Prix race on a circuit in the Anjou district, for cars having four-cylinder engines of not more than 130 mm. bore, and weighing not less than 900 Kg. But simultaneously both French and German manufacturers, who had found motor racing an increasing burden, decided by a large majority vote to abstain from all long-distance events; in consequence, by December 31st, 1908, only three teams had been entered for the A.C.F. Grand Prix, wherein forty cars constituted a quorum, and the event was abandoned.

In 1909 proposals for a 1910 Grand Prix race were brought forward but were negatived by the racing committee of the Automobile Club, a decision which, however, reflected not international, but inter-company rivalry. The victories of Fiat in 1907 and Mercedes in 1908 were unfortunate, but although " foreigners " they were world famous firms who had entered the industry right at its beginnings. What the older constructors who dominated the Automobile Club de France could not stomach was the thought that a 1910 Grand Prix might be won by a newcomer such as Delage or Hispano Suiza, already conspicuous in Voiturette racing. At the same time, they felt that further Grand Prix victories could not benefit the well established companies.

Neither the public appetite for automobile racing, nor the desire of the younger and progressive companies to benefit therefrom, could however be stemmed by the autocratic action of the senior members of the Automobile Club de France.

As far back as 1905 the French paper, *L'Auto,* had put up a cup for the best performance in an event for cars with engines of less than one-litre capacity and running in touring trim. The full history of the subsequent competitive events organised by this enterprising paper (and others) in the next eight years is set out in *Racing Voiturettes* * by Kent Karslake, and it is sufficient to record in this work that in 1908 the Grand Prix race was preceded by an event run over 286 miles of the same circuit for cars with engines having pistons not more than 65, 80 or 100 mm. diameter with four, two or single cylinders respectively.

The winning Delage had a single-cylinder engine and averaged 49.8 m.p.h. on total distance but the fastest lap was put up at 54.3 m.p.h. by a 1.96-litre single-cylinder Sizaire-Naudin. The events of the next three years on the Boulogne circuit affected powerfully subsequent Grand Prix racing and are recorded in the next chapter.

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CHAPTER FOUR

Peugeot Supremacy and The German Challenge

RACING STATISTICS 1911-14

Date	*Event*	*Course*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Lap Speed (Rec'd **
30/11/11	American G.P.	Savannah	D. Bruce Brown	Fiat	74.75	—
23/7/11	G.P. de France	Le Mans	V. Hemery	Fiat	56.71	67.75*
25/6/12	French G.P.	Dieppe Circuit	G. Boillot	Peugeot	68.45	—
25/6/12	,,	,,	D. Bruce Brown	Fiat	—	76.8
9/9/12	G.P. de France	Le Mans	J. Goux	Peugeot	74.56	—
9/9/12	,,	,,	G. Boillot	Peugeot	—	80*
12/7/13	French G.P.	Amiens	G. Boillot	Peugeot	71.65	—
12/7/13	,,	,,	P. Bablot	Delage	—	76.6*
5/8/13	G.P. de France	Le Mans	P. Bablot	Delage	76.8	82.5*
21/9/13	Coupe de l'Auto	Boulogne	G. Boillot	Peugeot	63.15	—
21/9/13	,,	,,	J. Goux	Peugeot	—	65.5*
30/5/13	500 Mile Sweepstake	Indianapolis	J. Goux	Peugeot	75.92	—
30/5/13	,,	,,	P. Zuccarelli	Peugeot	—	93.5*
30/5/14	500MileSweepstake	Indianapolis	R. Thomas	Delage	82.47	—
3015114	,,	,,	G. Boillot	Peugeot	—	99.5*
10/6/14	R.A.C., T.T.	Isle of Man	K. Lee Guinness	Sunbeam	56.44	59.3*
5/7/14	French G.P.	Lyons	C. Lautenschlager	Mercedes	65.5	—
517114	,,	,,	M. Sailer	Mercedes	—	69.95

DURING the three racing seasons 1909, 1910 and 1911, during which Grand Prix racing was in abeyance, development took place along the lines which were relevant to the subsequent history of the Grand Prix car. In the first place, although the overwhelming majority of the established manufacturers of Europe voted against further participation in racing after 1908, a minority party, formed by Fiat and others, although not strong enough to keep Grand Prix racing itself alive, were nevertheless continuously active in competition work. Fiat, in particular, built a number of special hill climb and record-breaking cars developed from their 1908 type, with bore and stroke successively increased until in 1910 they produced their 300 h.p. Grand Prix record-breaking

model with four cylinders and a bore and stroke of 190 x 250 mm. equal to a swept volume of 28.4 litres. They also continued to produce road racing types of more modest dimensions and with these competed both in America and in various European hill climbs and club competitions. In 1910, for example, Nazzaro broke the lap record in the American Grand Prize race before being forced to retire with a broken chain, and in the following year a Fiat car won this event after averaging 74.75 m.p.h. for 411 miles.

In Europe, circuit racing as such was confined to Voiturettes and the success of the race for small cars which had preceded the 1908 Grand Prix encouraged the proprietors of L'Auto to organise a race in 1909 over a 23½-mile circuit on the outskirts of Boulogne.

We are, fortunately, in a position directly to assess the effects of this competition, for it happened that at the end of 1908 a Sizaire-Naudin, of the type which had put up the fastest Voiturette lap speed at Dieppe, established class records at Brooklands track in which, with remarkable consistency, it covered 65.43 miles in an hour with a timed speed of 66.48 m.p.h. over the half-mile.

The regulations for the 1909 event are dealt with in the third section of this book and it will suffice now to remark that they led to engines with exaggerated stroke/bore ratios. This tendency had already been witnessed in 1908 in which the single-cylinder Sizaire-Naudin had a bore and stroke of 100 x 250 mm. and a crankshaft speed of 2,400 r.p.m. and the Lion-Peugeot Co. adopted the same proportions for their single-cylinder engine in the following year. This model was supplemented by a two-cylinder having axes with an included angle of 16 deg. and bore and stroke of 80 x 192 mm.

A variation on the same theme was the four-cylinder engine designed by Birkigt for Hispano-Suiza which had a bore and stroke of 65 x 140 mm. Thus, when the race was run on 20th June, 1909, there were single-, two-, and four-cylinder cars in competition, all with stroke/bore ratios of between 2.15 and 2.5 : 1, with crank speeds running up to little over 2,000 r.p.m. and piston speeds reaching up to 3,500 ft./min. In the event a single-cylinder Lion-Peugeot made the fastest lap of the circuit at 55 m.p.h., but due to a pit stop the winner was a two-cylinder type of the same general design. The four-cylinder Hispano-Suizas were all substantially slower and a subsequent event makes it safe for us to conclude that at this time the single-cylinder Lion-Peugeot was the fastest example of this type of racing car. This was the arrival of Boillot on a single-cylinder Lion-Peugeot at Brooklands track in November, 1909, successfully to attack the existing Sizaire-Naudin records by covering 68.39 miles in an hour and a half-mile at an average of 72.3 m.p.h. This proves beyond question that cars of 1909 were substantially faster than their 1908 Dieppe predecessors and shows that although the lap speed rose by only 0.7 m.p.h. this must have been because the Boulogne circuit was far more difficult than the prior Grand Prix course.

The 1909 successes of the Lion-Peugeot cars were not confined to the Boulogne circuit for they also won races in Spain and Sicily. In 1910 they repeated their successes, firstly on the famous Madonie circuit and then in Spain at Sitges. They were then using their 1909 type cars, the only serious competition to which came from the Hispano-Suizas which retained four cylinders with a bore of 65 mm. and a stroke enlarged to 180 mm. The 1910 Coupe de l'Auto race had exceptional interest and was once more run on the Boulogne circuit. For this the Lion-Peugeot designer, Monsieur Michaux, discarded the single-cylinder engine and increased the stroke of the 16 deg.

V-twin to 180 mm., thus providing 2.8 litres swept volume with a stroke/bore ratio of no less than 3.5 : 1. This was supplemented by a 3.44-litre V-four engine which by regulations was restricted to a bore of 65 mm. and which with a stroke of 260 mm. reached the record stroke/bore ratio of 4 : 1. On the four-cylinder Hispano-Suizas, Birkigt was influenced by manufacturing convenience to choose a 3 : 1 ratio, giving the dimensions of 65 x 200 mm. and a capacity of 2.65 litres. Partly owing to tyre and chassis troubles which beset the two-cylinder Peugeot, the four-cylinder Hispano-Suiza driven by Zuccarelli won this event and had a best lap of 58 m.p.h. The two-cylinder Lion-Peugeot actually put up the record lap of 59 m.p.h., which represents the very substantial gain of 7.3 per cent. over the previous year.

The four-cylinder Peugeot was a failure, but once again the two-cylinder model was brought to Brooklands, and in the autumn of 1910, despite the handicap of an exhaust system imposed by final regulations, covered 75.25 miles in one hour, the half-mile speed, owing to a head wind, being somewhat slower than this.

For 1911 the regulations for the Coupe de l'Auto were substantially revised, mudguards being demanded and the engine capacity limited to 3 litres with varying combinations of bore and stroke up to 2.0 : 1. The result in the case of the Lion-Peugeot was to produce another Michaux design following the V-four formula with bore and stroke 78 x 156 mm. the two principal drivers Goux and Boillot now being assisted by Zuccarelli. Birkigt withdrew from racing after his 1910 success, but the loss of Hispano-Suiza was balanced by the return of Delage with a four-cylinder engine 80 x 149 mm. with horizontal valves and a five-speed gearbox with direct drive on fourth. This type of car proved the winner on a lengthened circuit which was lapped at 59.7 m.p.h.. by Boillot's Peugeot which finished second, Goux of this team retiring with mechanical trouble and Zuccarelli overturning on the first lap.

Whilst all these road racing activities continued on the Continent, parallel developments in small car engines were taking place in Great Britain where, since 1907, the steeply-banked 2.7-mile Brooklands track had proved a real forcing ground for high-speed development. In the 3-litre category Vauxhall and Sunbeam were the principal contenders, the latter running supreme in class for engines with less than 31 sq. in. of piston area and the former almost monopolising the class for cars with up to 39 sq. in. of piston area. Whereas, however, Louis Coatalen of Sunbeam followed the long-stroke theory with 80 x 149 mm. engines, Laurence H. Pomeroy upheld the short-stroke argument for Vauxhall with 90 x 120 mm. engines, there being negligible difference in their swept volumes. In the end Sunbeams proved to be slightly faster. They put up their first record in October, 1910, with 71.95 m.p.h., over the half-mile, raised this to 86.16 m.p.h. in April, 1911, and then to no less than 101.87 m.p.h. in October, 1912. Vauxhall, on the other hand, were faster in December, 1909, with a speed of 88.618 m.p.h. than were Sunbeam two years later. Moreover in October, 1910, they put up speeds of 97.15 m.p.h., 98.109 m.p.h., and finally 100.083 and thus became the first 3-litre cars to reach three figures. The final speed of this model was 101.24 m.p.h., made in November, 1912, in an unsuccessful effort to beat the Sunbeam maximum.

The speed of both cars was noticeably assisted by very narrow low-drag bodies, but the enormous disproportion between the 75 m.p.h. of the Peugeot and the 100 m.p.h. of the Vauxhall in 1910 was also due to a very real superiority in engine design expressed as h.p. per litre. Both Vauxhall and Sunbeam reaped the benefits of

Brooklands in 1912 road racing. In that year the Coupe de 1'Auto race for 3-litre cars was run conjointly with a Grand Prix organised by the Automobile Club de France. This had been preceded in 1911 by an event called The Grand Prix of France, approved by the Automobile Club de France but actually organised by the Automobile Club de la Sarthe. It was run over a 33¾-mile circuit adjacent to Le Mans, but over entirely different roads to those used in 1906, and owing to continued opposition to racing by the Automobile Manufacturers' Association in France there was a very poor entry, victory going to a 10-litre Fiat which is described as Example No. 2 in this volume.

Out of these tentative beginnings of a revival the Automobile Club de France were emboldened to stage a full-scale Grand Prix Race in 1912. They chose the Dieppe Circuit used in 1907 and 1908, and went back to the precedent of 1906 in making the race a two-day affair, 477.4 miles being covered on each day. The only limitation placed on entries was the somewhat odd one of a maximum width of 1.75 metres (5 ft. 9 in.), but concurrently they had a section for cars with engines of under three litres capacity, having a stroke not less, nor greater than, twice the bore and not fewer than four cylinders. These cars had to weigh a minimum of 800 Kg. (1,763 lb.), and as they were thought to have no chance of beating the larger entrants, they were offered a special cup put up by the proprietors of the French paper, *I'Auto.* This class proved extremely popular, and of the fifty-six total entries received, forty-two were competitors for the Coupe de l'Auto. Seven of them, comprising the Sunbeam team of four cars and the Vauxhall team of three, actively intervened in the struggle for the Grand Prix itself. In the big car class teams were entered by three French manufacturers, Lorraine-Dietrich, Peugeot and Rolland-Pilain, and one each from Belgium and Italy, Excelsior and Fiat respectively.

It will be observed that Fiat and Lorraine-Dietrich, were the only companies with prior experience of Grand Prix racing and it is, therefore, not a coincidence that they had by far the largest engines in the race with a swept volume of 15 litres, for they were continuing the tradition built up by competition in the Gordon Bennett, and early Grand Prix series. Both cars also retained chain drive, and Fiat held to wooden wheels with detachable rims, although detachable wire wheels had been tried before the race. Fiats, however, were not wholly wrapped in the mist of antiquity, for they embodied the overhead camshaft type of engine which they had been developing during the past two racing seasons.

Peugeot entered for their first Grand Prix with some 7.6-litre cars of startling technical novelty. Nominally designed by the Chief Engineer, they were in reality the work of a young Swiss designer, Henri, who designed them in co-operation with two of the drivers, Zuccarelli and Georges Boillot. The engine used a phenomenally high piston speed with a completely novel valve gear design, utilising for the first time inclined valves with two overhead camshafts and four valves per cylinder.

The Sunbeams and Vauxhalls both had four-cylinder side valve engines, which had been intensely developed in competition at Brooklands.

It is difficult to compare the small and large cars on an h.p. basis, as designers were apt to over-estimate power output somewhat for reasons of propaganda, but 200 b.h.p. was claimed for the Fiat, 175 b.h.p. for Peugeot, and 80 h.p. at 2,800 r.p.m. for Sunbeam. The last-named figure, equivalent to a b.m.e.p. of 124 lb. per sq. in.,

seems very high, and it would perhaps be safer to rewrite the above figures as more like 160 b.h.p., 135 and 65 respectively.

The race disclosed that the Fiats were undoubtedly the fastest cars entered and, once again, we find the curious feature of many early Grands Prix, that the first (standing) lap was the fastest of the day. This was achieved by Bruce-Brown on a Fiat, at 76.8 m.p.h., that is to say, faster than the 1907 Fiat (75.4 m.p.h.), but slower than the 1908 Mercedes (78.5 m.p.h.). Later Boillot's Peugeot lapped at 75 m.p.h.

The 1912 race was twice the length of these prior events, which may have held down the speed and Bruce-Brown maintained his lead with complete regularity during the ten laps of the first day to average 72.4 m.p.h. Following him with almost equal precision was Boillot on one of the Peugeots (71.2 m.p.h.), the other two of the team speedily developing trouble with faulty petrol lines. Wagner kept a Fiat steadily in the third position (68.3 m.p.h.), the third Fiat being out, also with a broken fuel line. No other " unlimited " cars were in the picture at all, fourth, fifth and sixth positions being held throughout by the 3-litre Sunbeams and Vauxhalls. Hancock on one of the latter led the class (and was fourth in the race) on laps six, seven and eight, but at the end of the day's run was third in the Coupe de l'Auto behind the Sunbeams of Resta and Rigal, and sixth in general classification.

During the second day, the incredible infection of broken fuel pipes spread to the leading Fiat, which ran out of petrol, leaving Boillot sufficiently ahead of Wagner to stave off competition. These cars ran first and second over the last six laps, and the collapse of all the other large cars brought Rigal's Sunbeam into third place in the Grand Prix race. The Hancock Vauxhall retired on the fifteenth lap, so Sunbeams had no difficulty in finishing first, second, and third in the Coupe de l'Auto, and third, fourth and fifth in the Grand Prix. The final speeds were :–

Peugeot	Boillot	68.45 m.p.h.
Fiat	Wagner	67.32 m.p.h.
Sunbeam	Rigal	65.29 m.p.h.

The winning speed was slower than that recorded by both the previous winners over this course, and whereas in 1908 over twenty cars were timed to exceed 100 m.p.h., in 1912 the maximum speeds recorded by the most prominent makes were :–

Fiat	Bruce-Brown ..	101.67 m.p.h.
Peugeot	Boillot	99.86 m.p.h.
Sunbeam	Resta	84.73 m.p.h.
Vauxhall	Hancock	78.76 m.p.h.

The Grand Prix de France (in contradistinction to the Grand Prix de l'Automobile Club de France) was again run in 1912 by the Sarthe Club over the 33¾-mile course used in 1911. It was sub-divided into a race for cars of up to 3-litre capacity, and unlimited engine size, the events being run concurrently. Only Peugeot, with two of their Grand Prix models, were serious contenders in the larger section in which Boillot put up the fastest lap in 25 mins. 9 secs. (approximately 80 m.p.h.) from a standing start away from the pits. Goux won on the sister car at an average speed for twelve laps of 74.56 m.p.h., both figures showing a great improvement on anything hitherto recorded on this course.

The large entries for the 1912 Grand Prix gave the A.C.F. great encouragement when preparing the 1913 event. A new circuit was chosen, measuring 19.52 miles, near

Amiens and twenty-nine laps had to be covered in one day, making the total distance 566 miles. A maximum fuel consumption formula was revived, but with the permitted amount reduced by one-third compared to 1907, and for the first time the intentions of the A.C.F. in 1906 were put into effect, and the race run clockwise. This led to what is now the common practice of having the grandstand on the outside of the course so as to give free access, but the pits being placed on the inside so that cars could continue to pull in without endangering other competitors. A tunnel was dug beneath the track to permit people to cross between the pits and the stand.

The short lap was designed to provoke spectator interest by virtue of more frequent passing, but for the first time the faster cars might be running a lap ahead of the slower ones, a source of confusion which has continued in practically all subsequent Grand Prix events.

The severe limitation on fuel rendered new designs essential. The organisers must, therefore, have been relieved to obtain an entry of twenty cars, comprising three French, two German manufacturers and one each from Belgium, Italy and Great Britain.

All cars had live rear axles and detachable wheels, and on the Rudge Whitworth type used by Peugeot the now traditional " ears " appeared on the locking rings, so that for the first time these could be removed by a hammer without the use of a special spanner. Itala used rotary valves, Opel and Peugeot inclined o.h.v. with two and four valves per cylinder respectively. Delage also used four valves placed horizontally in the head, the remainder of the entries having L-headed engines. All had four cylinders except Sunbeam and Excelsior, who used six.

An entry of Mercedes cars by the Belgian agent, Pilette, was refused, and the race was won fairly easily by Peugeot. Boillot led from the seventeenth to the twenty-ninth lap and averaged 71.65 m.p.h. ; Goux ran second at 71.29 m.p.h., and a Sunbeam was third at 69.81 m.p.h.

All the leading cars finished with plenty of petrol in hand, Boillot with six and Goux with nearly five gallons left in the tank, out of their total allocation of 40.5 gallons.

A Delage made the fastest lap at 76.6 m.p.h., and another of these cars actually led from the tenth to the sixteenth lap, losing the position on the seventeenth by a strange incident when Guyot's mechanic jumped too soon before a tyre stop and was run over. This caused a loss-of about 30 minutes.

Despite the Delage fastest lap, Peugeot put up the best speed over a timed flying kilometre, the figures recorded by the three fastest makes being :–

Peugeot	Boillot	97.26 m.p.h.
Delage	Bablot	92.21 m.p.h.
Sunbeam	Resta	88.77 m.p;h.

The growing gap between modified production models as typified by Sunbeam, and pure racing designs, is well exemplified in the above figures, whilst the entry list of the 1913 event reflects the change that was going on in the French automobile industry. All the historic grandes marques of France-Panhard, Mors, Clement Bayard, Renault, Richard Brasier, and so on-had dropped out of racing. The standard was now held by the younger concerns, who, although prominent in races for small cars in the 1909-l1 period, were relative newcomers to the Grande Epreuve. Few, even of the

latter, supported the 1913 Sarthe Club Grand Prix, run on the previous course, but reduced in distance to ten laps. There were Schneiders and Excelsiors which had run in mediocre fashion at Amiens, the much more formidable Grand Prix Delages, and the " Pilette " Mercedes which had been excluded from the previous event. The latter were of great technical interest, for although Fiat retired from racing for 1913, in order to develop new designs, Mercedes decided to make some practical experiments with different types of cars. In the Sarthe race they ran two 7.5-litre six-cylinder cars (105 x 140 mm.), a 9.25-litre four-cylinder (140 x 150 mm.) and another, 8.9-litre, four-cylinder of 130 x 170 mm. All the cars had chain drive, and (although a 1912 Grand Prix Lorraine Dietrich, driven by Szisz, won the 1914 Anjou Race at 65.9 m.p.h. with three passengers) this was the last appearance of chains in Grand Prix racing.

The smaller of the four-cylinder engines had Knight double sleeve valves but the power units of the other models were virtually replicas of the 75-85 h.p. aero engines developed by the company during 1912. They had a single overhead camshaft operating two inclined valves per cylinder, the latter being made in pairs with welded steel water jackets. Although not so fast as the Delage cars in this race the Mercedes team constantly threatened them and after holding 3rd, 4th and 5th positions at half distance Pilette was lying second on the penultimate lap, with his colleagues 4th, 5th and 7th. On the last lap, however, Pilette was forced to yield a place by reason of a tyre failure so that the Delages came home in 1st and 2nd positions.

The winner, Bablot, averaged 76.8 m.p.h. for ten laps, aggregating 337.5 miles. He also put up the record lap of 82.5 m.p.h. (once more from a standing start, after a pit stop). Both speeds were road racing records, which show the 1913 Delage cars were faster than the Peugeots of the previous year.

The rapid rate of technical development from 1910 onwards was even more strongly marked in the 3-litre cars which ran in the 1913 Coupe de l'Auto over the same circuit at Boulogne that had been employed in 1911, and for this event Vauxhall and Sunbeam used cars very similar to the models which had put up such sensational performances at Dieppe in 1912. An unsuccessful contender in that race had been a Henri-designed 78 x 156 mm. car with the typical four inclined valves per cylinder operated from two overhead camshafts, but this engine placed in a modified chassis put up an absolutely sensational performance on the 1913 Boulogne circuit. The winner, Boillot, had a winning time of 6 hrs. 7 min. 40 secs., including two pit stops, whereas Sunbeams, who were the fastest rival make, took third place, the driver, K. Lee Guiness, taking 6 hrs. 18 min. 50 secs. for a non-stop run. In respect of lap speeds, the Peugeot put in a circuit at 66 m.p.h., whereas Sunbeams could do no better than 61 m.p.h. Peugeots then confirmed their ascendancy in this class by achieving 105.81 m.p.h. at Brooklands using a single-seater body, the previous fastest speed with this size of engine being 101.87 standing to the credit of Sunbeams.

The 3-litre cars came into direct competition with Grand Prix models in the 500-mile Sweepstake race held at Indianapolis on May 30th, 1914. The previous year Peugeot had been the first European car to win this event, using one of their 1912 7.6-litre Grand Prix cars which (Goux driving) averaged 75.92 m.p.h. Prior to the race three laps were covered at an average of 93.5 m.p.h. In 1914, Peugeot and Delage used their 1913 Grand Prix cars, and to them was added, as a private entry, a 3-litre

Coupe de l'Auto Peugeot, which had been sold following that race. Boillot on the big Peugeot averaged nearly 100 m.p.h. on a practice lap, but René Thomas, on one of the Delages, led from the 40th to the 100th mile, and (with a brief intermission) from the 200th to the 500th mile, to finish first at an average of 82.47 m.p.h. The 3-litre Peugeot finished second, averaging 80.89 m.p.h., and the best of the works team was Goux, who after many troubles finished fourth at 79.49 m.p.h.

The Peugeot performance was a complete vindication of those who believed in the technical development of the small capacity, high power per litre, prime mover. Organising clubs, in addition to engineers, were impressed by this theme, and the two major races in Europe in 1914 were both run under a restriction of engine swept volume, the first time such a rule had been operative since the 1907 Kaiser Prize event. Whereas, however, the size in that year had been the substantial one of 8 litres, in the 1914 races the cars were limited to engines of 190 cubic inches (3,310 c.c.) for the Tourist Trophy and 4½ litres for the Grand Prix.

The race for the smaller cars was organised by the Royal Automobile Club and run in the Isle of Man on the 10th and 11 th June over an aggregate of 600 miles. It was won easily at an average speed of 56.44 m.p.h., by K. Lee Guinness on a Sunbeam, who also broke the lap record at 59.3 m.p.h. The Sunbeam is of technical interest, in that the engine was an interchangeable replica (except for an enlargement of bore by 3 mm. and stroke by 4 mm.) of the 1913 Coupe de l'Auto Peugeot, all the parts being copied from one of these cars purchased in France some months before the race. Humber and Vauxhall also ran cars which reflected Peugeot influence in having two overhead camshafts, but they were otherwise of original design. Their promise was, in neither case, fulfilled.

Vauxhall and Sunbeam also entered for the 1914 A.C.F. race, which has been termed " The Greatest Grand Prix." The organising club chose a 23.3-mile circuit on the outskirts of Lyons, which had to be covered twenty times, making up a distance of 466 miles and the entry, both in quantity and quality, had not been bettered previously and has never been equalled since. With the exception of the U.S.A., all the motor manufacturing countries of the world were represented, and an entry of fourteen teams, making a total of forty-one cars, was received.

These reflected the immense change in thought which had been wrought by the success of the Peugeot designs. Apart from the sleeve-valve Piccard Pictets, every car in the race was of the overhead camshaft type, Delage, Peugeot, Sunbeam, Vauxhall and Nagant having double camshafts, and all except Fiat and Aquila Italiana four valves per cylinder. Delage and Nagant went so far as to have a mechanical arrangement for closing the valves. Non-detachable cylinder heads were used without exception, and only Mercedes departed from the practice of casting the cylinders in one block. In this German design, however, separate cylinders made from steel forgings with welded up valve ports and water jackets were used, a continuation of the 1913 practice which was to be followed by Mercedes for the ensuing twenty-five years and to be extensively used by other makers.

Even more important than any engine development was the use by Delage, Peugeot, Fiat and Piccard Pictet of brakes on all four wheels. This scheme had been used on touring cars from 1909 onwards and by the Isotta Fraschini racing cars which ran at Indianapolis in 1913 and in the Vanderbilt Cup race run in California in February,

1914. Despite these anticipations, the Lyons event is the true turning-point in racing car history, for no subsequent Grand Prix has been won by a car braked only upon the rear wheels.

Survey of the entries shows that two of the great names in racing, Fiat and Mercedes, had returned to the fray after a retirement lasting twelve months and six years respectively. Mercedes, in particular, made every effort by design, preparation and team control to win the race, although Opel can probably claim to have had their cars completed before anyone, as they were running six months before the event. By contrast, both Sunbeam and Vauxhall were the last to finish their cars, lack of preparation on the latter entirely ruining the chances of a highly promising design.

The race itself was notable for a constant and fierce international and inter-company duel. The cars left in pairs at 30 secs. intervals from 8 a.m. onwards, the three last cars to leave being the Mercedes of Salzer, Wagner and Pilette. Mercedes had five cars entered, and Sailer was dedicated to the task of opening up the race and setting a pace that no one could equal. He led for the first five laps, putting up a record for the course on the fourth lap, at 69.95 m.p.h. He was hotly pursued by the hitherto invincible Peugeot, driven by the rarely beaten Boillot, who, despite going flat out, was nevertheless 2 mins. 44 sets. in arrears at quarter distance. Behind him were Duray on a Delage (third) and Lautenschlager (Mercedes) fourth.

Sailer retired with a broken crankshaft in lap six and thenceforth the drama lay in the struggle between the technical superiority of the Mercedes design and the professional virtuosity of Boillot's driving. From quarter to three-quarter distance the Peugeot star was in the ascendant, Boillot putting in his seventh lap at 68.85 m.p.h., and being only a decimal point slower on his ninth. Both cars made replenishment stops just past half distance (Lautenschlager on the eleventh and Boillot on the twelfth lap), and owing to inferior pit work Lautenschlager lost over two minutes in the process. Already behind he had to work off a deficit of two minutes twenty-four seconds in the last five laps to win. On the sixteenth lap he pulled back 13 seconds and on the seventeenth lap, one minute 51 seconds, due to a pit stop for tyres by Boillot. On the eighteenth lap, Lautenschlager put in his fastest lap of the race at 68.7 m.p.h., which brought him 23 seconds ahead of Boillot, who at this critical point took a minute longer than on his fastest lap. On the nineteenth lap he was even slower, so that when Lautenschlager started on the twentieth circuit he had a lead of 67 seconds. In a last desperate effort, Boillot broke a valve on the Peugeot engine, and was led weeping from his car. He had struggled against a technically superior product for six and a half hours over an exceptionally arduous circuit, in the course of which he had been forced to change tyres eight times compared with the German's four stops for this purpose. The question is asked, did tyres cost Peugeot the race ? The true answer would seem to be that indirectly they were a handicap for reasons which are set out in the next chapter, but one must also consider that Boillot's hard driving may well have made engine failure inevitable.

However one answers these questions, one must agree that as a team the German cars clearly proved their superiority, in that they were able to secure an overwhelming victory, filling the first three positions by playing a waiting game and going ahead into the lead in response to orders from the pit. Lautenschlager averaged 65.83 m.p.h., Wagner ran second at 65.3 m.p.h. (and did a lap at 69.02 m.p.h.), and Salzer was third

at 64.8 m.p.h. Goux on a Peugeot finished fourth at 63.94 m.p.h., Resta on a Sunbeam was fifth at 62.46 m.p.h.

Within a month of this German victory, the first world war was declared, and European racing was at an end. The 1914 Grand Prix cars were, however, to renew their competition in subsequent years, during the war in the U.S.A., and immediately thereafter at Brooklands.

CHAPTER FIVE

Wartime Racing and a 1914 Revaluation

RACING STATISTICS 1915-16

Date	*Event*	*Course*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Lap Speed*
30/5/15	500 Mile Sweepstake	Indianapolis	R. de Palma	Mercedes	89.84	98.6
26/6/15	300 Mile Chicago Derby	Chicago Board	D. Resta	Peugeot	97.58	—
7/8/15	100 Mile Race	Chicago Board	D. Resta	Peugeot	101.86	—
30/5/16	300 Mile Sweepstake	Indianapolis	D. Resta	Peugeot	83.26	—
11/6/16	Chicago Derby	Chicago Board	D. Resta	Peugeot	98.61	—
15/7/16	150 Mile Race	Omaha	D. Resta	Peugeot	99.02	—
16/7/16	50 Mile Race	Omaha	R. de Palma	Mercedes	103.45	—
30/9/16	Astor Cup	Sheepshead Bay Tracl	J. Aitken	Peugeot	104.8	—
28/10/16	Harkness Trophy	Sheepshead Bay Tracl	J. Aitken	Peugeot	105.95	—

WITH racing at an end in Europe Peugeot decided to send three, and Sunbeam two, of their 1914 Grand Prix cars across the Atlantic to compete in U.S.A. 1915 events. In the same year the well-known Italian-born U.S. driver, Ralph de Palma, secured one of the victorious 4½-litre Mercedes team and raced it as a private entry.

The year opened with an easy victory for Peugeot, driven by Resta, in the Vanderbilt Cup race held over a very rough circuit at San Francisco, the average speed being only 67.6 m.p.h. In this race only, he drove a 1913 Grand Prix car.

The remainder of the year's racing was on board or brick tracks and commenced with the Chicago Derby for 300 miles over which distance Resta calculated that an average of 98 m.p.h. would suffice to win ; he did in fact secure first position at an average of 97.58 m.p.h., but this speed would have been insufficient if trouble had not overtaken one of the Sunbeams, which led at 40 miles distance with an average of 103 m.p.h. and covered 100 miles at 99.7 m.p.h. Later in the year Resta drove the 1914 Peugeot at an average of 101.86 m.p.h. for the 100 mile race on the same track.

As always, the principal U.S.A. race was the 500 Mile Sweepstake at Indianapolis. De Palma reserved the Mercedes for this event and in practice put up the fastest average of 98.6 m.p.h., Resta doing 98.5 m.p.h. on a Peugeot and Porporato 95.1 m.p.h. on a Sunbeam. Resta led the race for the first 100 miles and was notably faster than the Mercedes on the straights. On the other hand he was slower on the turns, and in the final stages was passed by the Mercedes, which won at 89.84 m.p.h., Resta being second

at 88.91 m.p.h. The only other European entry which achieved any prominence was the Sunbeam on which Porporato averaged 91 m.p.h. for the first 50 miles, but at 163 miles he retired with a seized piston. The second Sunbeam, driven by Van Raalte, suffered many delays due to a loose magneto platform and finished tenth, after which both cars were returned to England.

The Peugeot and Mercedes remained in the U.S.A. for 1916 and were joined by four of the 1914 Delage Grand Prix cars, which had proved disappointing at Lyons after very promising practice speeds. In this year the Indianapolis race was the first major event on the calendar, and with de Palma and the Mercedes absent, Peugeots scored another success. Of the three cars entered, one retired on the twenty-seventh lap, another driven by Resta was first at 83.26 m.p.h., and the third car third at 82.6 m.p.h. The Delages were again disappointing, only one finishing, fifth at 79.2 m.p.h. It is worth noting that over the first 25 miles the fastest Peugeot averaged 98.6 m.p.h. and the best Delage 91.2 m.p.h., also that owing to rain making the track dangerous the contest was stopped when the leading car had covered 300 miles.

Twelve days after Indianapolis the Mercedes versus Peugeot battle was re-enacted on the Chicago board track in the 300 Mile Chicago Derby. For nearly three hours the two cars ran bonnet to bonnet, but with only four miles to go a plug failed on the Mercedes when de Palma had a very short lead. He was forced to go into the pits, and as an obvious consequence the Peugeot (again driven by Resta) won at 98.6 m.p.h., the Mercedes coming home 1 min. 54 secs. behind at 97.6 m.p.h. Everyone agreed that this was an unfortunate ending to a closely contested struggle, and a little later a match race, run in three heats, was arranged, On this occasion the Peugeot showed a clear superiority by winning all three heats and over 24 miles averaged 105.1 m.p.h., compared with 104.5 m.p.h. for the Mercedes. The Peugeot also made the best lap at 109.75 m.p.h. This was not the full extent of Resta’s victories at the wheel of the Peugeot. He also won the 250 mile “ Grand American ” at 103.99 m.p.h. on the Chicago track, the Vanderbilt Trophy at a new track in San Francisco at 86.95 m.p.h. and a 150 mile event at Omaha at 99.02 m.p.h. In this last named meeting de Palma declined competition with the Peugeot but ran in an alternative 50 mile race over the same circuit, which he won on the Mercedes at 103.45 m.p.h. This was the sole victory for the German car, but two further Peugeot wins were scored by Aitkin, who won the Astor Cup at Sheepshead Bay at an average of 104.8 m.p.h. and the Harkness Trophy on the same course at 105.95 m.p.h., the distances being 250 miles and 100 miles respectively. The Delages appeared in the former event but their best speed was 95.8 m.p.h., confirming previous evidence that the speed of this make was well below that of the Mercedes, Peugeot and Sunbeam cars. In 1917 the U.S.A. entered in the 1914-18 War and for two years racing was entirely at an end.

With the return of peace a number of 1914 Grand Prix entrants re-appeared, including Vauxhall, who ran two of their Lyons cars at Brooklands during the 1921 season. These are amongst the few entirely British-designed and British-made Grand Prix models, and analysis of their design suggests that they may claim to be amongst the best of the cars which had been sent down to Lyons seven years previously. The Brooklands performances bear this out, for in the course of a highly successful season one driven by E. Swain averaged 101 m.p.h. over 8½ miles from the standing start and put in a lap at a speed of 108.74 m.p.h.

During 1921, also, another car from the winning Mercedes team was being

handled by Count L. Zborowski, and in this case the best Brooklands average was 97.75 m.p.h. over 8½ miles and the lap speed 104.19 m.p.h.

At Lyons in 1914 the Mercedes was faster than the Peugeot, but subsequently on the really fast board tracks of the U.S.A. the Peugeot was faster than the Mercedes ; at Indianapolis the speeds were almost equal. These apparent contradictions can be explained by assuming that the Mercedes was superior in engine output and in low speed torque, and that the Peugeot had the better aerodynamic form. Hence, at Lyons, where high speeds were rarely obtained, the former would secure the advantage and on the board tracks running at 100 m.p.h. the Peugeot would be the faster. Indianapolis, where the speed varied between 85 and 110 m.p.h., would be a course where neither car would secure any special benefit from the leading feature in its design and here one would expect an equality of result, as was proved in practice.

An extremely interesting theory was put forward in 1942 by Major Galliot, a close friend of Boillot, who watched the whole of the 1914 Lyons race. According to his evidence the Peugeot team made an unfortunate choice of tyres, and Boillot in particular stopped at his pit on every lap before continuing past the timing box. The failure on his car was caused by a broken exhaust valve in No. 3 cylinder and at least one lap was made on three cylinders in the hope of retaining the lead. At the end of the race Boillot said that his car was 6 m.p.h. faster on the straights and " with my front wheel brakes (the Mercedes had none) I ridiculed them on the short bends on the road."

On this evidence the Peugeot was inherently capable of lapping 23.3 miles in 19 mins. 30 secs. compared with the best Mercedes lap of 20 mins. 7 secs., and these figures, it is interesting to observe, bring the relative performance of the cars at Lyons almost exactly into line with their subsequent times in the U.S.A. But with due respect to an eye-witness, this cannot literally be correct.. At Lyons the timing posts were placed 100 yards behind the starting line, but the Peugeot pits were only 75 yards behind the starting line, so that both on the first and on all subsequent laps Boillot must have been timed before he made a tyre replacement. Jules Goux, one of the Peugeot team drivers, has said that the downfall of the car lay in the streamlined tail which embraced two spare wheels mounted lengthways on in order to reduce wind resistance. In order to keep the height within reasonable bounds, the whole of this mass had to be mounted well behind the rear axle and very poor road holding at high speeds resulted, many of the tyre stops being made to change the type of tread and pressure rather than by reason of the wear or burst covers. This explanation from first-hand certainly fits the known facts and should still a controversy which has lasted for nearly forty years.

The failure of the Vauxhall cars in 1914 is explained by their hurried preparation, which led to minor troubles, but the exceedingly high Brooklands speeds (achieved with an absolutely square tailed body) are an indication of excellent engine design and unusually high power output. This is consistent with a shorter engine stroke and larger piston area than were used on the Continental cars, so that whereas Peugeot and Mercedes represent the apotheosis of the long stroke 2,500 r.p.m. type of engine, Vauxhall was the genesis of the high speed type which has since become universal.

A further increase of engine speeds occurred immediately after the 1914-18 war with the introduction of multi-cylinder engines, as will be disclosed in the following chapter.

CHAPTER SIX

A Post-War Revival

RACING STATISTICS 1919-21

Date	*Event*	*Course*	*Driver*	*Car*	*Winning Average Speed*	*Lap Speed m.p.h.*
30/5/19	500 Mile Sweepstake	Indianapolis	H. Wilcox	Peugeot	87.95	—
,,	”	”	R. Thomas	Ballot	—	104.7*
23/11/19	Targa Florio	Madonie	A. Boillot	Peugeot	34.19	—
30/5/20	500 Mile Sweepstake	Indianapolis	G. Chevrolet	Monroe	88.5	—
”	”	”	R. de Palma	Ballot	—	99.15
30/5/21	500 Mile Sweepstake	Indianapolis	T. Milton	Frontenac	89.62	—
,,	”	,,	R. de Palma	Ballot	—	100.75
26/7/21	French G.P.	Le Mans	J. Murphy	Duesenberg	78.1	84.0*
12/9/21	Italian G.P.	Brescia	J. Goux	Ballot	90.4	—
”	”	,,	P. Bordino	Fiat	—	96.31*
22/6/22	Tourist Trophy	I. of M.	J. Chassagne	Sunbeam	55.78	—
”	,,	”	H. O. D. Segrave	Sunbeam	—	62.5 (P)
30/5/22	500 Mile Sweepstake	Indianapolis	J. Murphy	Murphy Special	94.48	100.5

NOTE-The 1922 events included above were run under the 1921 formula. * Record

THE armistice between Germany and the Allies was signed on November 11 th, 1918. Shortly afterwards, the R.A.C. in England and the Manufacturers' Association in France decided to withhold their support from racing during 1919 and there were, in consequence, only two races in that year, the 500 Mile Sweepstake at Indianapolis and the Targa Florio. The former was held on the usual date of May 30th under a capacity limit of 300 cubic inches, or 4,917 c.c., and although such a short time had elapsed since the end of hostilities the entries included four entirely new designs by Packard and Duesenberg in the U.S.A., and Sunbeam and Ballot in Europe.

The two six-cylinder Sunbeams had been designed and made in the factory at Wolverhampton during the course of the war under the guise of being experimental aviation work. The subterfuges by which these jobs were “ hidden up ” when Air Ministry inspectors went round the works is a story in itself, but, alas ! all this effort was in vain, as the cars were withdrawn ; some say because the engines were found to have a capacity of 4,924 c.c. (and were thus over size) ; others because Resta's report on the torsional oscillations in the crank at 2,500 r.p.m. was decisive.

Belief in the latter version is reinforced by measurements made later by Brooklands scrutineers, which gave the capacity as 4,914 c.c. It is unlikely that the pistons and blocks had been changed after the cars came back to England.

The remaining four European cars were the sensation of the race, for they introduced a new name to motor racing-Ballot. They were designed by Ernest Henri, built in the amazingly short time of 101 days, and had eight-cylinder engines, made of two blocks of four, bore and stroke 74 x 140 mm.

M. Ballot was the head of a company which had been making automobile engines for many years and he decided to make an entry on Christmas Eve, 1918. The cars had to leave Paris not later than April 26th, so there remained but 120 days in which to build and test the vehicles. M. Henri was retained as designer and, naturally, the general layout of the cars bore a certain resemblance to the four-cylinder Peugeot he had made from 1912-14. The decision to use a straight-eight layout was undoubtedly the result of his contact, during the war, with a Bugatti-designed straight-eight engine for aviation use. Duesenberg had also been concerned with the manufacture of the Bugatti engine in the U.S.A. and they also entered a straight-eight engine.

The background to this development and the immense formative influence of the Bugatti aero engine on all subsequent racing cars are fully dealt with on other pages. For the moment we are concerned with the immediate effect upon contemporary racing.

During practice the Ballots proved themselves the fastest cars on the track. Unfortunately, they also proved to the team manager's satisfaction that the gear ratio was rather too high and, as they had no spare crown wheels and pinions, the wheels were exchanged for an American type, using straight-sided tyres. This proved a disaster ; trouble started within the first 100 miles and persisted throughout the race. The Duesenberg eight-cylinder proved itself nearly as fast as the Ballot, but none of the new European designs were able to better the speed of either the Packard or the old 1914 Peugeot Grand Prix models.

R. de Palma, driving the Packard (which had a V.12 engine, 60 x 114.5 mm.), covered the first 125 miles at an average of 92.2 m.p.h. and sustained over 92 m.p.h. for the first 150 miles, after which he had to come in for a very long stop during which all four tyres were changed and a new exhaust valve was fitted to No. 1 cylinder of the left bank. He had further trouble with a broken front wheel bearing, and for the whole distance could do no better than 81.05 m.p.h. and sixth position. One of three 4½-litre Peugeots, privately entered by an American driver, Wilcox, was third at 125 miles, second at 225 miles and in the lead thereafter to win at 87.95 m.p.h. A second 4½-litre, driven by Goux, another of the same size driven by Klein, both retired, as did a 3-litre 1913 Coupe de I'Auto model driven by Howard, and a 2½-litre designed for the 1914 Coupe de l'Auto, which was never run. This last was driven by Andre Boillot, younger brother of Georges, who had been killed flying on the Western Front.

Only one other race was run in 1919, the Targa Florio, on November 23rd. There were twenty-one entries, technical interest being concentrated on three Fiats (ex-1914 Grand Prix), a Ballot straight-eight, and a 2½-litre Peugeot. The two last named had both run at Indianapolis, and owing to various troubles with the Fiats the race was again between a 1914 and a 1919 Henri design.

Despite having double the cylinder capacity of the small Peugeot, the larger car never managed to get to the lead and on the last lap the Ballot went out with a broken differential. The remaining challenger to the leader was an Itala, and the finish was dramatic in the extreme. Boillot throughout the race had been making up for the small capacity of the Peugeot by the most fantastic exhibition of driving without regard to personal safety. He had been six times off the road ; his refuelling consisted of picking up a can when on the move and filling the tank without stopping and, finally, as he arrived at the finish he found the crowd had overflowed on to the road. He jammed on the brakes, spun the car round, and crashed 10 yards before the finishing line. The excitable Sicilian crowd endeavoured to right the car, ignorant of the fact that they would thus ensure its disqualification. Boillot and his mechanic forcibly defended themselves, drove back 30 yards, turned round, and then won. Utterly exhausted, Boillot cried " *C'est pour la France* " and collapsed over the wheel.

After this event the 2½-litre Peugeot disappears from the racing world, but several of the 5-litre Ballots were brought to Brooklands. In their original form and tune they were able to lap the track at over 112 m.p.h. (Chassagne did 112.17 m.p.h. on September 25th, 1920), and their maximum speed was of the order of 115-l18 m.p.h.

In 1920 the European ban on racing was maintained and the only significant race was at Indianapolis, now run under an International 3-litre capacity limit. From a technical point of view interest was concentrated on the entry of three eight-cylinder Ballots, four eight-cylinder Duesenbergs and three four-cylinder Peugeots. The Ballot cylinders measured 65 x 112 mm. ; the Duesenberg 63.5 x 117 mm. ; and the Peugeot 80 x 149 mm.

Ballot had retained Henri in their employ and the new cars were scaled-down versions of the previous year's model, having, typically, the drive to twin overhead camshafts by a train of gears, and, as before, four valves per cylinder. Duesenberg were different, not only in respect of cylinder dimensions, but also by reason of having one camshaft only, driven by a vertical shaft and bevel pinions ; this worked three valves per cylinder, one inlet and two exhaust. The Peugeots had the remarkable number of five valves per cylinder, with two sparking plugs and three camshafts, but despite successful trials in France they were a complete failure in the race, due to cooling problems. This marked the end of Peugeot participation in large-scale racing.

In the preliminary trials, R. de Palma, on one of the 3-litre Ballots, put up the best time, doing nearly 100 m.p.h. ; during the race he led until only 35 miles remained. Unfortunately, his car caught fire and, although he restarted, it ran out of fuel and he could only finish fifth ; R. Thomas on a sister Ballot took second place. The race was won by a Monroe, which had an engine exceedingly like the 3-litre 78 x 156 mm. 1913 Peugeot engine, and thus was another successful follower of the Henri formula. The dimensions had been changed slightly to 79 x 152 mm.

The winning speed was 88.5 m.p.h. -a slight advance on the previous year's time, despite a reduction in engine capacity of 33 per cent.

Of the Duesenbergs, one finished third, despite a broken valve spring and having to change three tyres ; another fourth and another sixth. Of the first half-dozen finishers, one only (admittedly the winner) had a four-cylinder engine-the others were all straight-eights.

In 1921 Grand Prix racing was revived in Europe under the 3-litre capacity limit. But as usual Indianapolis was the first big race of the year and the entry list showed that the lesson of eight-cylinder superiority driven home in the previous year had been well digested.

Four-cylinder engines had powered 78 per cent of the entries in 1919 and 75 per cent in 1920, but in 1921 the straight-eight for the first time gained a clear majority, being used by 56 per cent of the entrants compared to 28 per cent for four-cylinder models. Ballot, Peugeot and “ S.T.D.” entered from Europe.

The single Ballot was identical with the previous year’s cars except for the addition of front brakes. Peugeot were 1913 Coupe de 1’Auto cars with much successful racing in America behind them.

The Sunbeams (or Talbot-Darracqs) were highly interesting. They were the first completely post-war racing models, for which Louis Coatalen was responsible, and there was no doubt that his team of designers modelled the engine fairly closely on the successful Ballot. The timing gears and camshaft layout were very similar ; the bore and stroke (65 x 112 mm.) identical. But four carburetters were fitted and owing to the use of plain in place of ball-bearing mains the cylinders were more widely spaced and the engine was longer.

Ballot for the third year in succession proved itself the fastest car on the track, and, for the third year in succession, failed to win. De Palma drove 200 miles at 93.6 m.p.h., easily a record, and broke a connecting rod. An eight-cylinder Frontenac then took the lead, and it was never displaced.

At 350 miles two “ S.T.D.” cars were lying third and fourth, but various incidents intervened, and eventually the best that could be managed was fifth place, at 84 m.p.h., over 5 m.p.h. slower than the winner’s average of 89.62 m.p.h. Seven Duesenbergs similar in design to those running the previous year were entered and finished second, sixth and eighth with four retirements. Again five out of the first six cars had eight in-line engines, which type also contributed 90 per cent of the finishers.

The G.P. of the Automobile Club de France was run in July over a 10.6 miles circuit at Le Mans with a first-class entry of sixteen cars from Ballot, Duesenberg, Fiat, Mathis and the S.T.D. combine.

The Duesenbergs were the first American entries in a European race since 1908, and were identical with the cars which had had two years’ running at Indianapolis (with front brakes added) ; in fact two out of the four cars had run in the American event some six weeks previously. The handicap of a three-speed gearbox was offset by remarkably good power output over the whole of the speed range of the engine which, although reaching a power peak at 4,250 r.p.m., could be taken up to 5,000 r.p.m. without damage. The brakes, hydraulically operated for the first time in road racing, were far more powerful and consistent than anything that had previously been known.

Ballot, also with Indianapolis experience, were likewise well advanced in their preparations, but this could not be said of either Fiat or the S.T.D. team. The former did not appear at all and the Coatalen-designed cars were formally withdrawn and then only brought to the line after super-human efforts by drivers and mechanics.

As the Mathis was a four-cylinder sports car of only 1½-litres capacity the race somewhat naturally resolved into a combat between Duesenberg and Ballot. The latter concern had little doubt about the outcome, but by the time the cars had sorted

themselves out on the third lap there were two white Duesenbergs first and second, and although on the eighth lap a Ballot, driven by Chassagne, became runner-up, Murphy's Duesenberg kept ahead with a record lap at 84 m.p.h. However, on the tenth lap the leader had a long pit stop as a consequence of which Chassagne led at the halfway mark and remained there until put out by a broken petrol pipe on the seventeenth lap. At this point the two remaining eight-cylinder Ballots were back in fifth and ninth places, so that despite a connecting rod failure on one of the Duesenbergs (on the eighteenth lap) and serious clutch slip on the other American car, Murphy was unchallenged and won at 78.1 m.p.h. De Palma brought home the fastest Ballot second, 15 minutes behind and averaged 73.6 m.p.h., third position being secured by a catalogue type four-cylinder 2-litre Ballot which had a non-stop run to average 71.8 m.p.h.

A second International Grand Prix was held later in the year on a circuit near Brescia. In this race some new Fiats turned up to compete with the Ballots.

The Fiat design had been prepared by a brilliant engineering team and, although featuring the straight-eight motif, it represented a considerable breakaway in constructional features, and differed in almost every material point from the racing cars which were then dominated by the Henri technique. Only two valves per cylinder were employed and the cylinder blocks were not made from iron castings, but from steel forgings welded together and enclosed by a sheet steel jacket.

This construction had been copied from the 1914 Grand Prix Mercedes, for immediately after the race at Lyons in that year the iron cylinder blocks of the 4½-litre Fiats were discarded and a welded-up steel type substituted. These cars were entered for the 1920 and 1921 Targa Florio races, and provided the winner in the latter year.

On the 3-litre car the popular dimensions of 65 x 112 mm. were adopted and a daring detail in design was the use of roller bearings for the main and big ends, coupled with a one-piece crankshaft. This arrangement involved the use of split cages and races for the bearings, an audacious expedient but one which proved entirely satisfactory and has since found a permanent place in engine design, the Fiat example having been followed by such famous concerns as Sunbeam, Delage and Mercedes-Benz.

With engines developing 120 b.h.p. at 4,600 r.p.m., Fiats had probably the fastest 3-litre unblown car which had been known, and one driven by Bordino lapped the Brescia circuit at 96.31 m.p.h., which compares with 93 m.p.h. as the best Ballot lap speed. However, over the full distance of the race Fiat had many minor troubles and could do no better than third place at 86.1 m.p.h., with Ballot first and second, Goux averaging 90.4 m.p.h.

The end of 1921 marks the end of the 3-litre and the beginning of a 2-litre limit for Grand Prix racing. There were, however, two major races for 3-litre cars in 1922, and as these may be considered a carry forward from 1921 they may be appropriately considered in this Chapter.

The Indianapolis organisers adhered to the 3-litre formula and the race was won at 94.48 m.p.h. by Murphy, using a Miller engine in the actual Duesenberg chassis which he had driven at Le Mans in 1921. The 1915 record speed was thus broken after standing for eight years and five races. A Ballot, driven by an American driver, finished third at 93.04 m.p.h.

In Europe the English R.A.C. resurrected the Tourist Trophy race last held in 1914 and ran it over the same course in the Isle of Man. Only nine entries were secured from Bentley, Sunbeam and Vauxhall.

The Bentleys were tuned-up standard productions, the Sunbeams had run in the 1921 French Grand Prix, and only the Vauxhalls were specially built ; they had engines designed by Ricardo. In view of the obviously high costs to the last company of building special cars it may seem odd that they should choose to enter a race under the virtually obsolete 3-litre formula and that they did not wait until the French Grand Prix and run 2-litre models which could have been kept going for some years.

The reason, believe it or not, was simple ignorance. The writer, as a very small schoolboy, remembers vividly the astonishment of the Chief Engineer when he disclosed the truth, for Vauxhall, up to that time, had been quite confident that the R.A.C. were complying with established international practice. As it happens, Vauxhalls did not even receive a reward for their enterprise and could do no better than third, first place being secured by Chassagne on a Sunbeam, and the runner-up being a Bentley. Despite this comparatively poor result in the Isle of Man it can be claimed with justification that these cars had the most efficient unsupercharged engines that have ever been made. They developed 129 b.h.p., the equivalent, therefore, of approximately 40 b.h.p. per litre and 3.7 b.h.p. per sq. in. of piston area. The former figure is not outstanding but the latter indicates that if Dr. Ricardo's skill had been exercised on a six-cylinder 2-litre engine of the same proportions as those used by Continental designers he would have produced an engine developing approximately 120 b.h.p., more than sufficient to win the French Grand Prix given reliability and good chassis design.

It is a real irony of motor racing that Vauxhall Motors Ltd. should have produced one of the three fastest 4½-litre cars to the 1914 formula and one of the two fastest cars of the 3-litre formula, and failed to secure international honours with either of them. That both of these models secured many successes in minor races, such as at Brooklands, in the later years of their lives, was a poor consolation.

CHAPTER SEVEN

The Two Litre Limit

RACING STATISTICS 1922-25

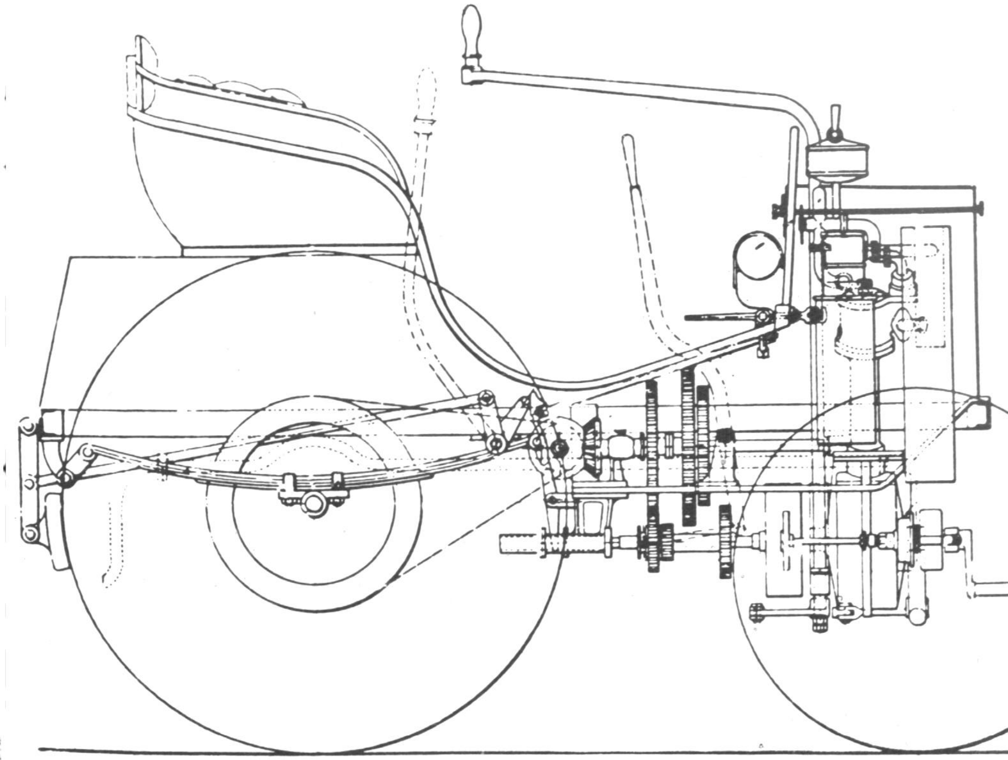
Date	*Event*	*Course*	*Driver*	*Car*	*Winning Average Speed*	*Lap Speed m.p.h.*
16/7/22	French G.P.	Strasbourg	F. Nazzaro	Fiat	79.2	—
16/7/22	„	„	P. Bordino	Fiat	—	87.75*
3/9/22	Italian G.P.	Monza	P. Bordino	Fiat	86.89	91.3*
30/5/23	500 Mile Sweep-stake	Indianapolis	T. Milton	H.C.S. Miller	90.95	108.17*
2/6/23	French G.P.	Tours	H. O. D. Segrave	Sunbeam	77.3	—
2/6/23	,,	,,	P. Bordino	Fiat	—	87.75*
9/9/23	European G.P.	Monza	C. Salamano	Fiat	91.06	—
9/9/23	,,	,,	P. Bordino	Fiat	—	99.8*
27/4/24	Targa Florio	Madonie	C. Werner	Mercedes	41.02	42.4
9/6/24	Circuit of Cremona	Cremona	A. Ascari	Alfa Romeo	98.3	100.8*
3/8/24	European G.P.	Lyons	G. Campari	Alfa Romeo	71	—
3/8/24	„	„	H. O. D. Segrave	Sunbeam	—	76.7*
25/9/24	Spanish G.P.	San Sebastian	H. O. D. Segrave	Sunbeam	64.12	—
25/9/24	„	„	M. Costantini	Bugatti	—	71.7*
19/10/24	Italian G.P.	Monza	A. Ascari	Alfa Romeo	98.76	104.24*
3/5/25	Targa Florio	Short Madonie	M. Costantini	Bugatti	44.5	45.1*
28/6/25	European G.P.	Spa	A. Ascari	Alfa Romeo	74.56	81.5*
26/7/25	French G.P.	Montlhéry	R. Benoist & A. Divo	Delage	69.7	—
26/7/25	,,	„	A. Divo	Delage	—	80.3*
6/9/25	Italian G.P.	Monza	Count G. Brilli-Peri	Alfa Romeo	94.76	—
6/9/25	„	,,	P. Kreis	Duesenberg	—	103.21
19/9/25	Spanish G.P.	San Sebastian	A. Divo	Delage	76.4	—
19/9/25	,,	,,	M. Costantini	Bugatti	—	82.75*

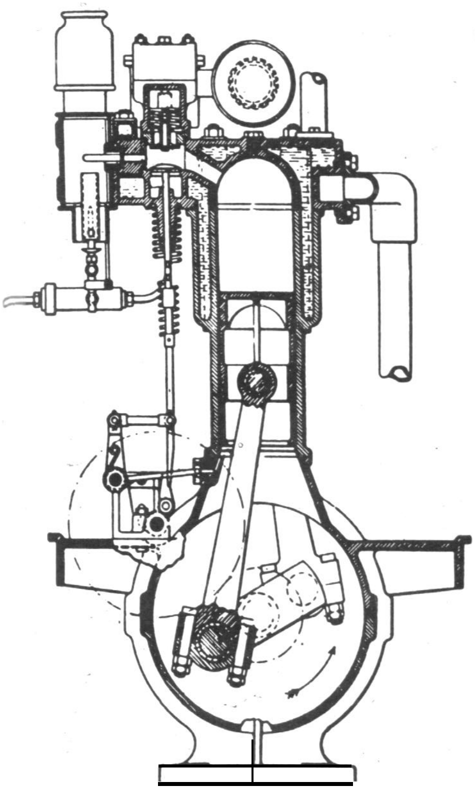
* Record

FROM 1922-25 the principal regulation governing racing cars was that they should have a cylinder volume not exceeding 2-litres. This of necessity led to entirely new designs, the first batch of which appeared on the starting line in the 1922 French Grand Prix held at Strasbourg on July 16th.

PLATE I

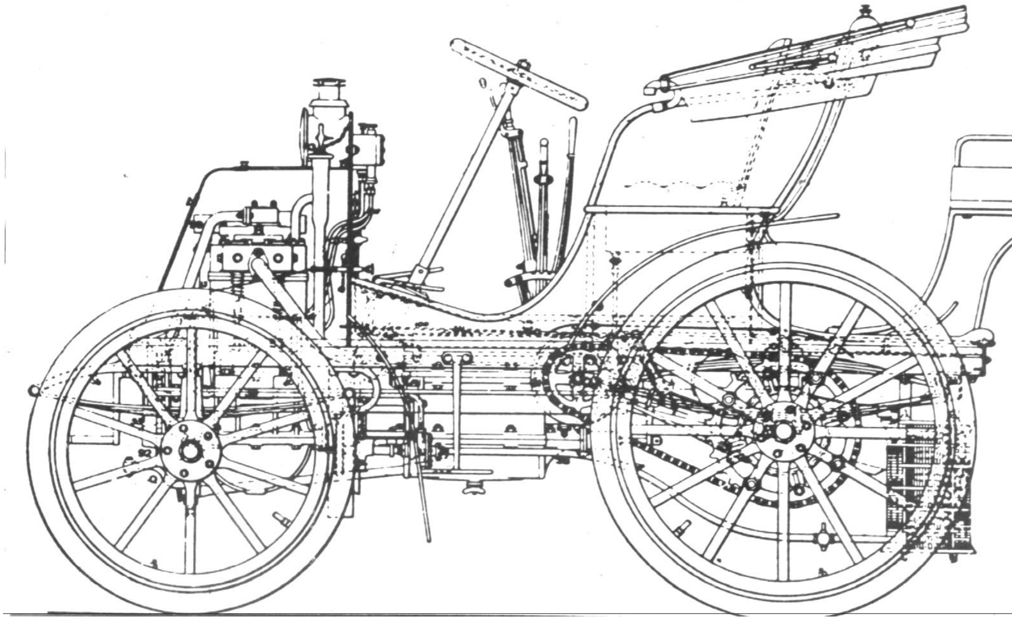
ORIGINAL ENTRY- This drawing to scale 1 : 25 is of the 1894 Panhard and Levassor, which averaged 10.7 m.p.h. from Paris to Rouen on July 23rd, the third highest speed for a petrol driven car. The 1.03-litre V-type engine was built under Daimler (Stuttgart) licence and developed about 3½ h.p. at 750 r.p.m., the gears giving four forward speeds were not enclosed.



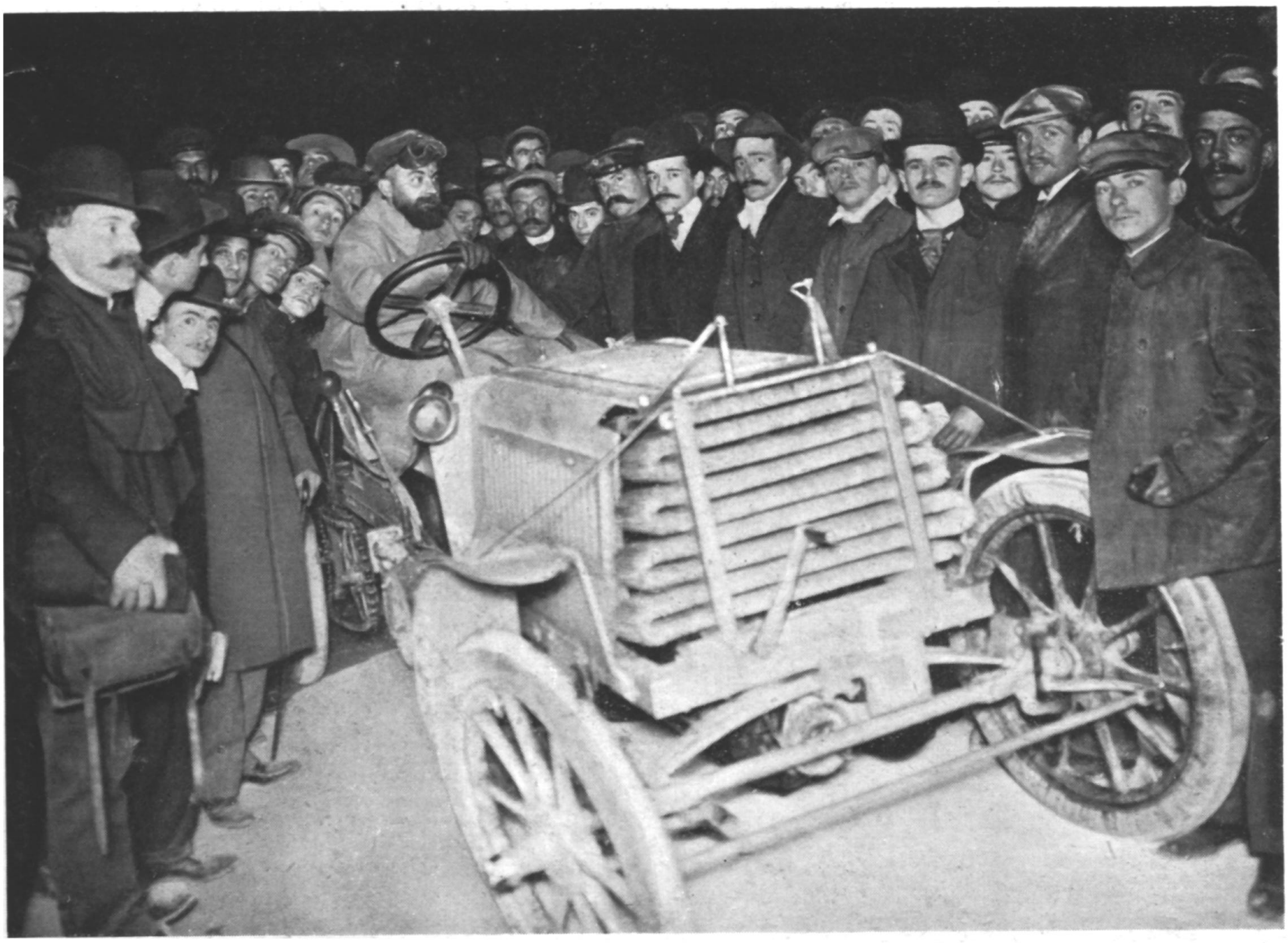


NINETEENTH-CENTURY PRACTICE-This cross section drawing (scale 1:10) shows the Phoenix Panhard engine built under Daimler (Stuttgart) licence in 1899. *The four-cylinder 3.3-litre model developed 12 h.p. and features of particular interest are the platinum tube ignition shown to the extreme left of the drawing, the suction operated overhead inlet valve and the levers between the camshaft and the valve stem which gave an interrupter effect to govern maximum r.p.m.*

FIN DU SIECLE - This-drawing is a side elevation (scale 1 : 25) of the 1899 Panhard and Levassor two-cylinder car. An identical car driven by Charron with a four-cylinder engine won the Paris-Bordeaux race of 351 miles at an average speed of 29.9 m.p.h.



EARLY WINNER-This photograph shows Girardot on his 7.4-litre 40 h.p. Panhard in the 1901 Gordon Bennett race which he won at an average speed of 37 m.p.h. for 372.6 miles.



PACE-MAKER - The Chevalier René de Knyff leaving Paris at 03.36 hours in the 1902 Gordon Bennett race on his 13.6-litre Panhard " 70. " He failed to finish but averaged 54.2 m.p.h. from Paris to Belfort, running on alcohol fuel.

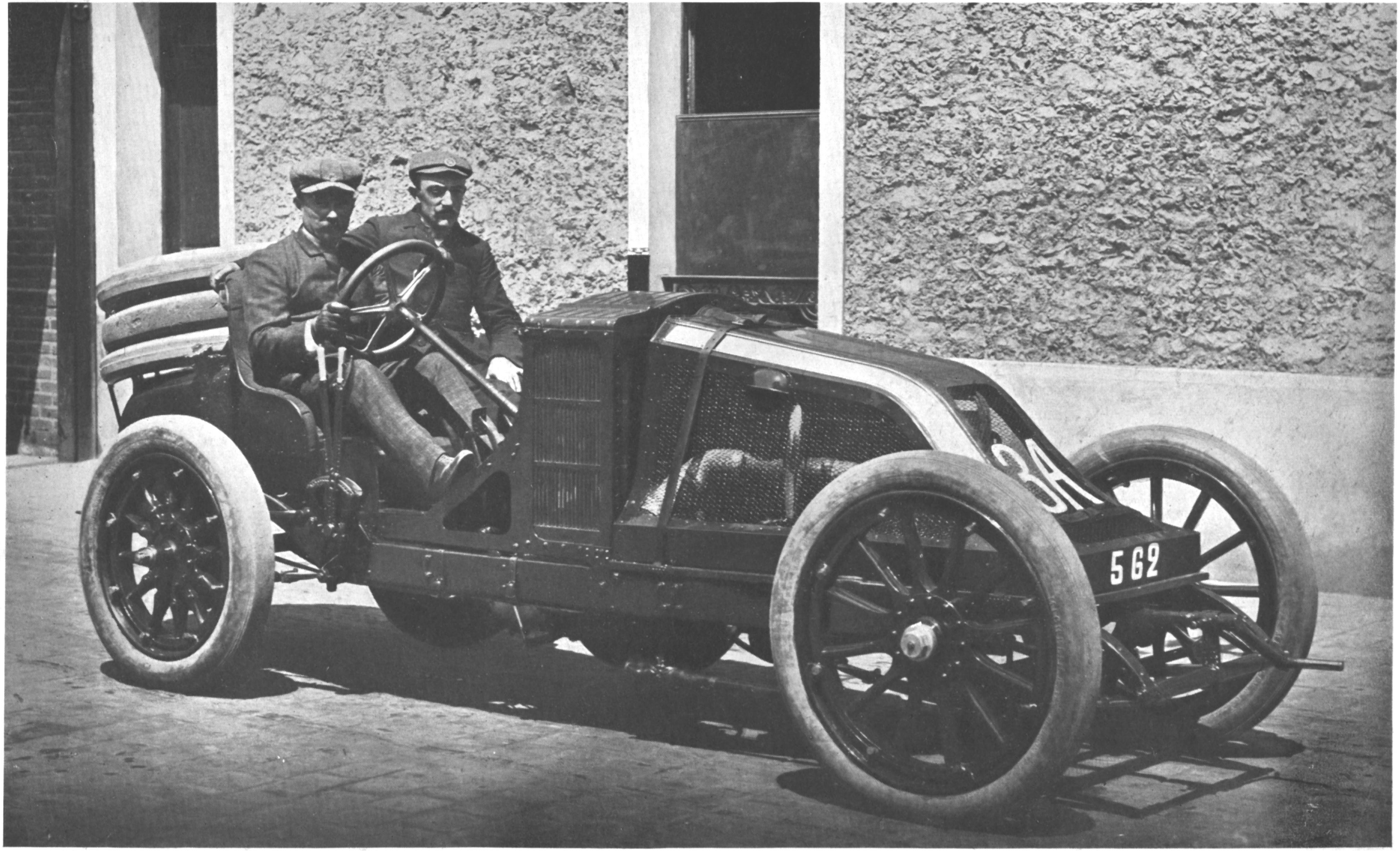


PLATE III

FIRST GRAND PRIX WINNER-The Hungarian, Szisz who won the first Grand Prix of the Automobile Club de France on June 26/27 1906, averaging 63 m.p.h. for 769.9 miles on the Sarthe course. He is here shown on the winning car, a 90 h.p. 13-litre, four-cylinder Renault with side valves and shaft drive.

PLATE IV

SECOND GRAND PRIX WINNER-The second Grand Prix de 1'A.C.F. run on July 7th, 1907, over 477.4 miles of the Dieppe Circuit, was won by Felice Nazzaro on a 130 h.p. Fiat car at 70.5 m.p.h. The four-cylinder o.h.v. engine had a capacity of 16 litres with chain drive to the wood wheels.

PLATE V

FOUNDING A LINE-The Grand Prix de l'A.C.F. and the Grand Prix de France in I912 were won by Georges Boillot and Jules Goux each driving a 7.6-litre Peugeot car, that driven by Goux being shown here. Combining for the first time such features as twin overhead camshqfts, four inclined valves per cylinder, shaft drive and detachable Rudge Whitworth wire wheels, these cars stand first in the line of modern tradition and began a continuous line of design which was consistently successful during the next ten years.

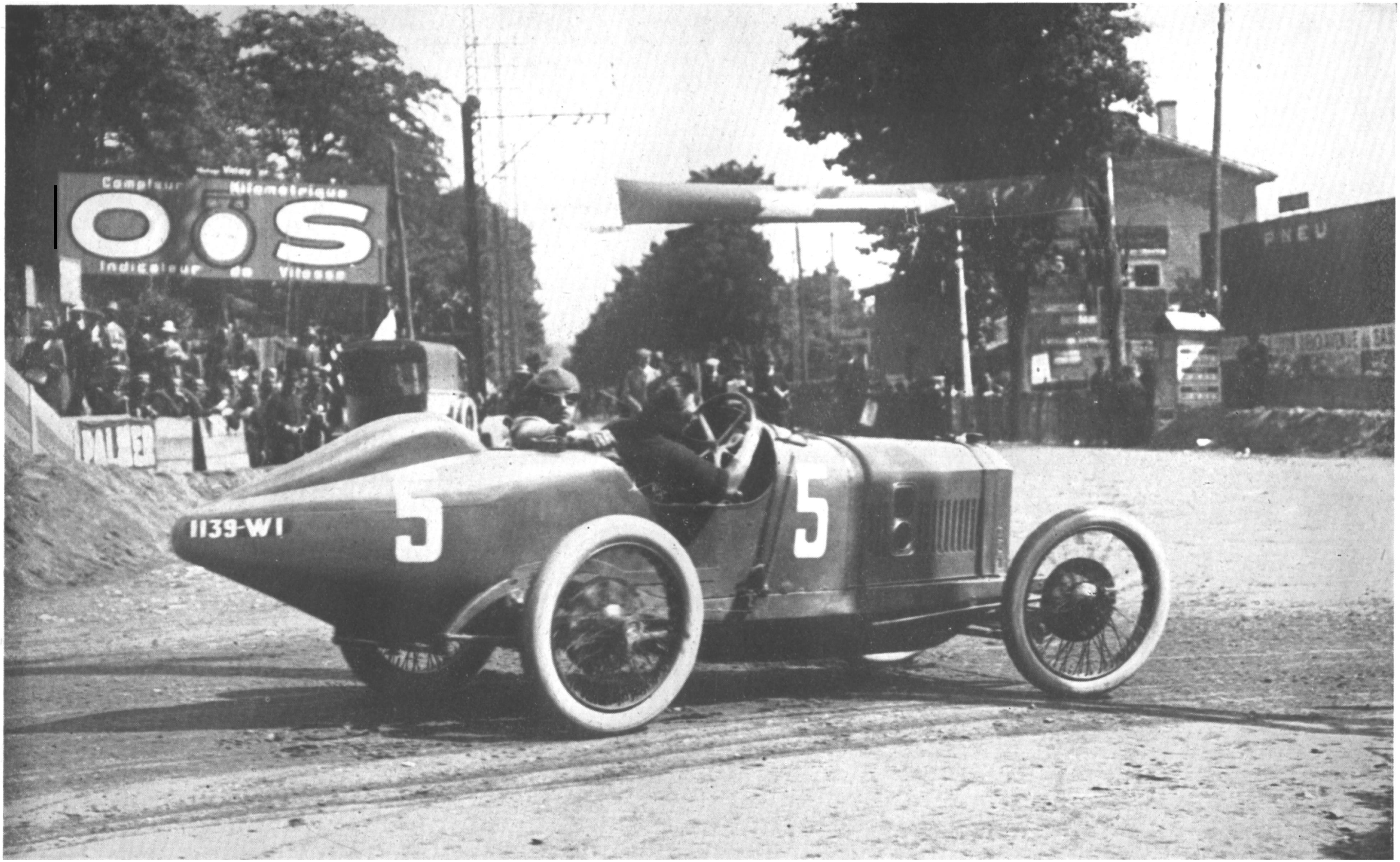


PLATE VI

SUCCESSFUL LOSER - Although Gorges Boillot, shown here in the 1914 4½-litre Peugeot, failed to prevent a 1, 2, 3 Mercedes victory at Lyons in 1914 his car pioneered many features which later became standard practice in racing. In addition to the twin overhead camshaft engine with crankshaft running on roller bearings, features which can he seen in this picture are front wheel brakes and the long streamlined tail. The latter housed two spare wheels, and it was the effect of their mass on the road holding of the car which mainly prevented the car from winning.

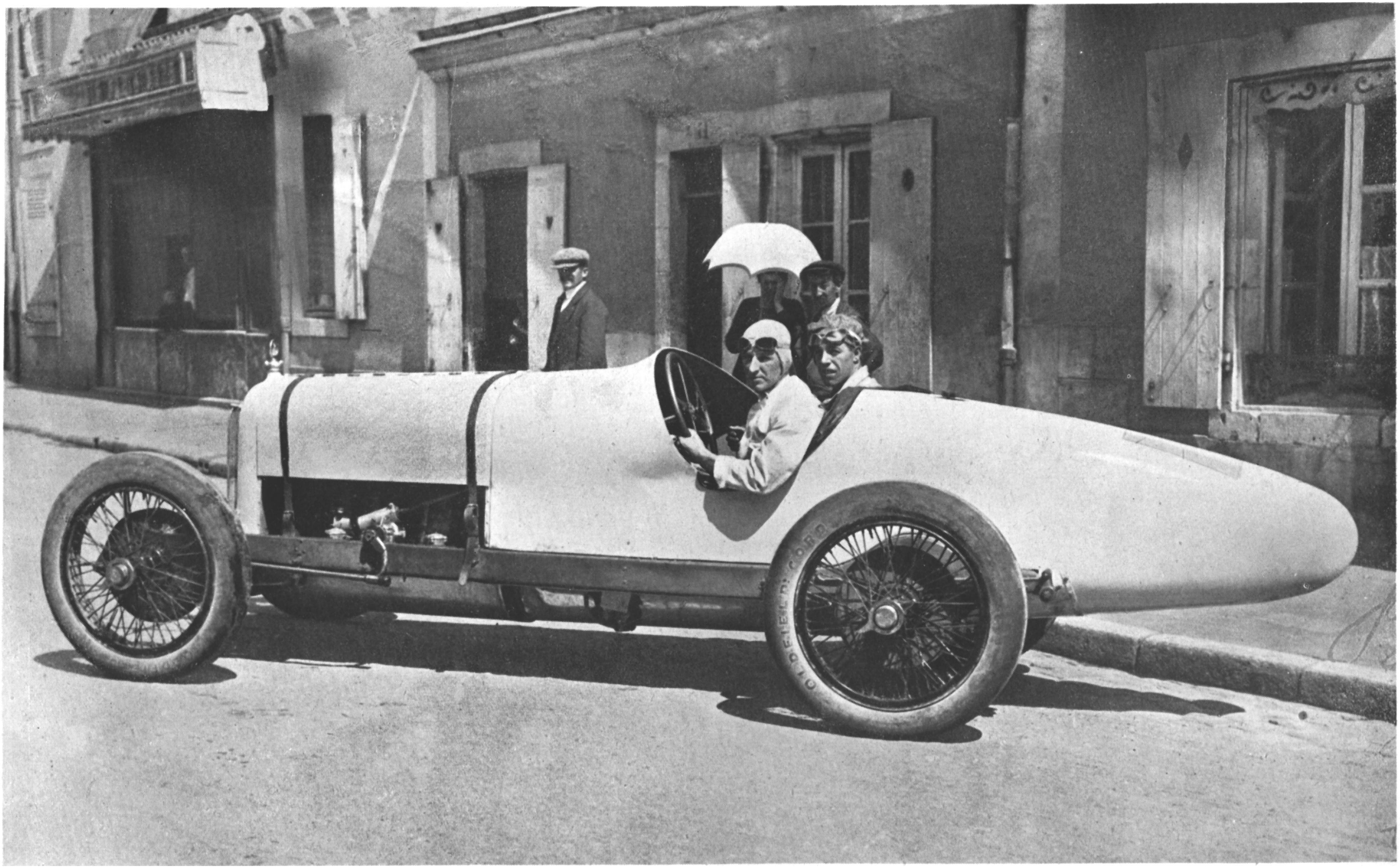


PLATE VII

FIRST FOR A CLASSIC TYPE - Since I920 straight-eight engines have powered the majority of successful racing cars. The first road race to be won with this type was the French Grand Prix of 1921 in which J. Murphy averaged 78.1 m.p.h. for 322 miles at Le Mans. The car was a Duesenberg, with a 3-litre engine giving 115 h.p. The driver in this picture is Joe Boyer.

PLATE VIII

SETTING A FASHION-F. Nazzaro on the 90 h.p. 2-litre six-cylinder Fiat with which he won the 1922 French Grand Prix at an average of 79.2 m.p.h. over 499 miles at Strasbourg. Both technically and in body form this design set a fashion which lasted for many years.

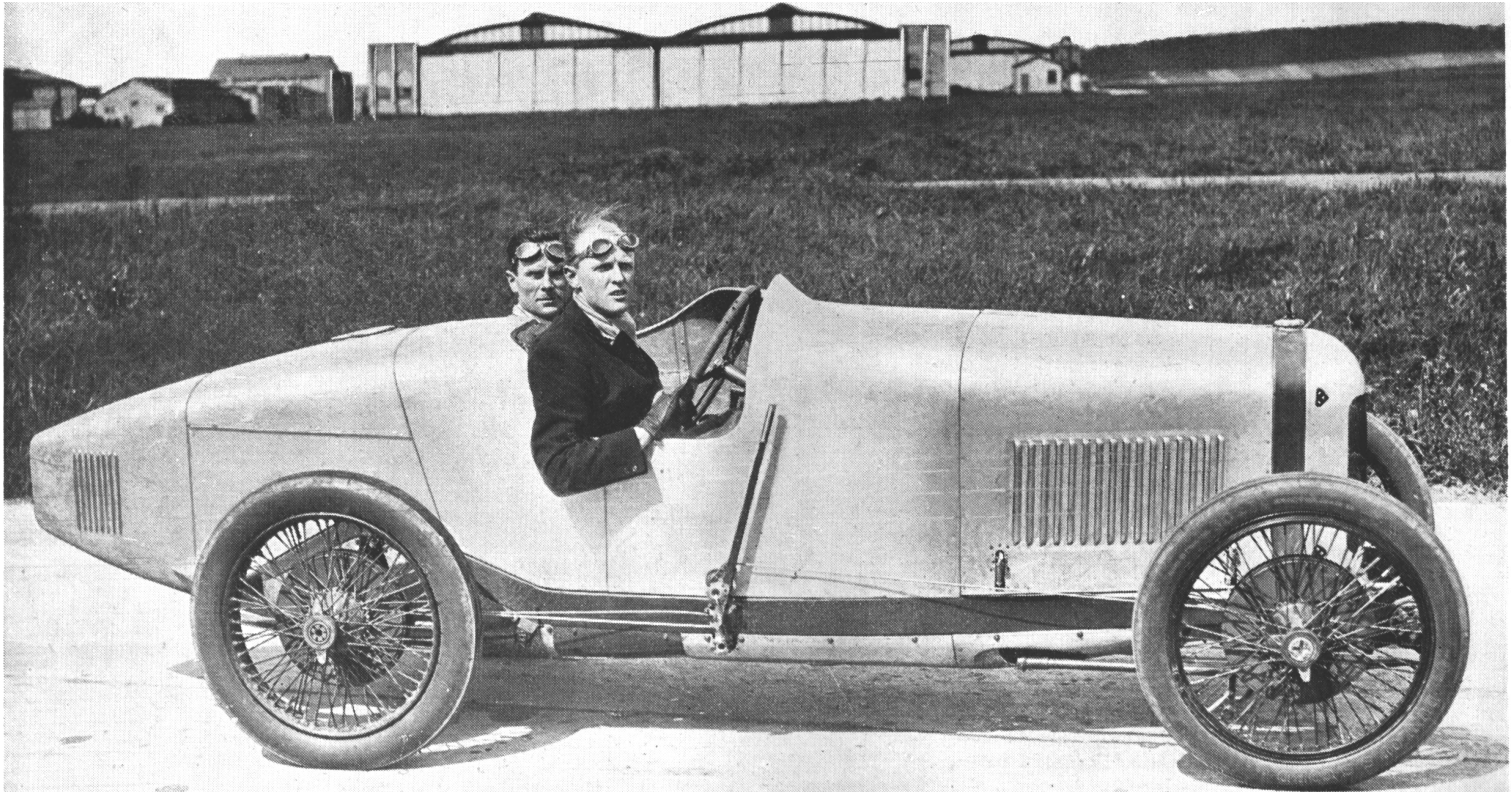


PLATE IX

BRITISH WINNER - Sir Henry Segrave on the six-cylinder 102 h.p. 2-litre Sunbeam photographed at Brooklands before winning 1923 French Grand Prix at an average of 75.3 m.p.h. for 496 miles at Tours.

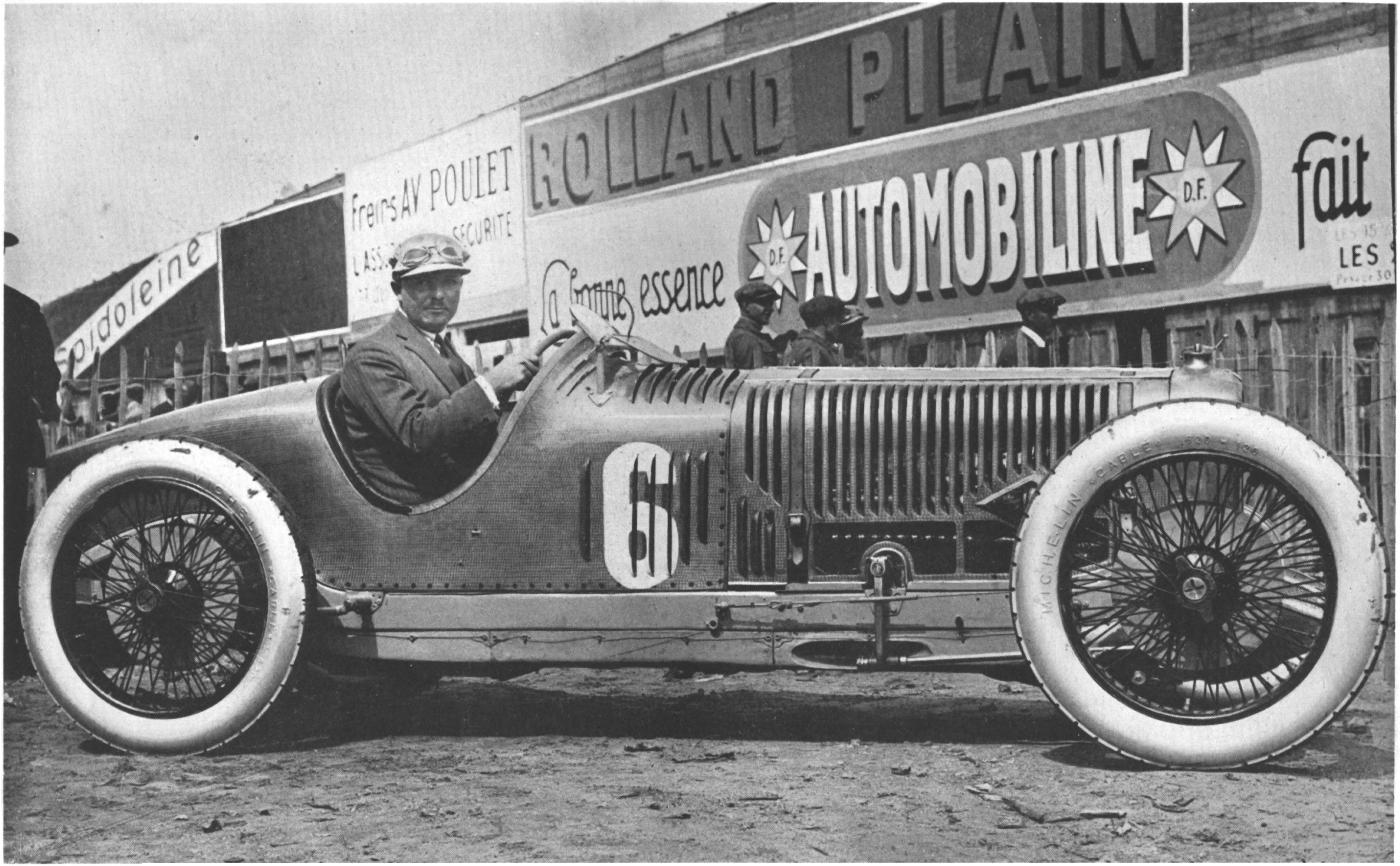


PLATE X

A PINNACLE OF DESIGN - The supercharged twelve-cylinder 2-litre Delage which won the French Grand Prixm at Montlhéry in 1925 at 69.7 m.p.h. for 621 miles. These cars would reach 134 m.p.h. with 190 h.p. available from the engine. At the wheel in this picture is A. Divo, who shared the wheel of the winning car (No. 14) and broke the lap record.

PLATE XI

A MASTER - Sir Henry Birkin, Bt. (refreshing himself with an orange), in the 4½-litre, four-cylinder, 240 h.p. supercharged Bentley, four-seater sports car, weighing two tons, which he drove into second place in the 1930 French Grand Prix at Pau at an average of 88.8 m.p.h. for 247 miles.

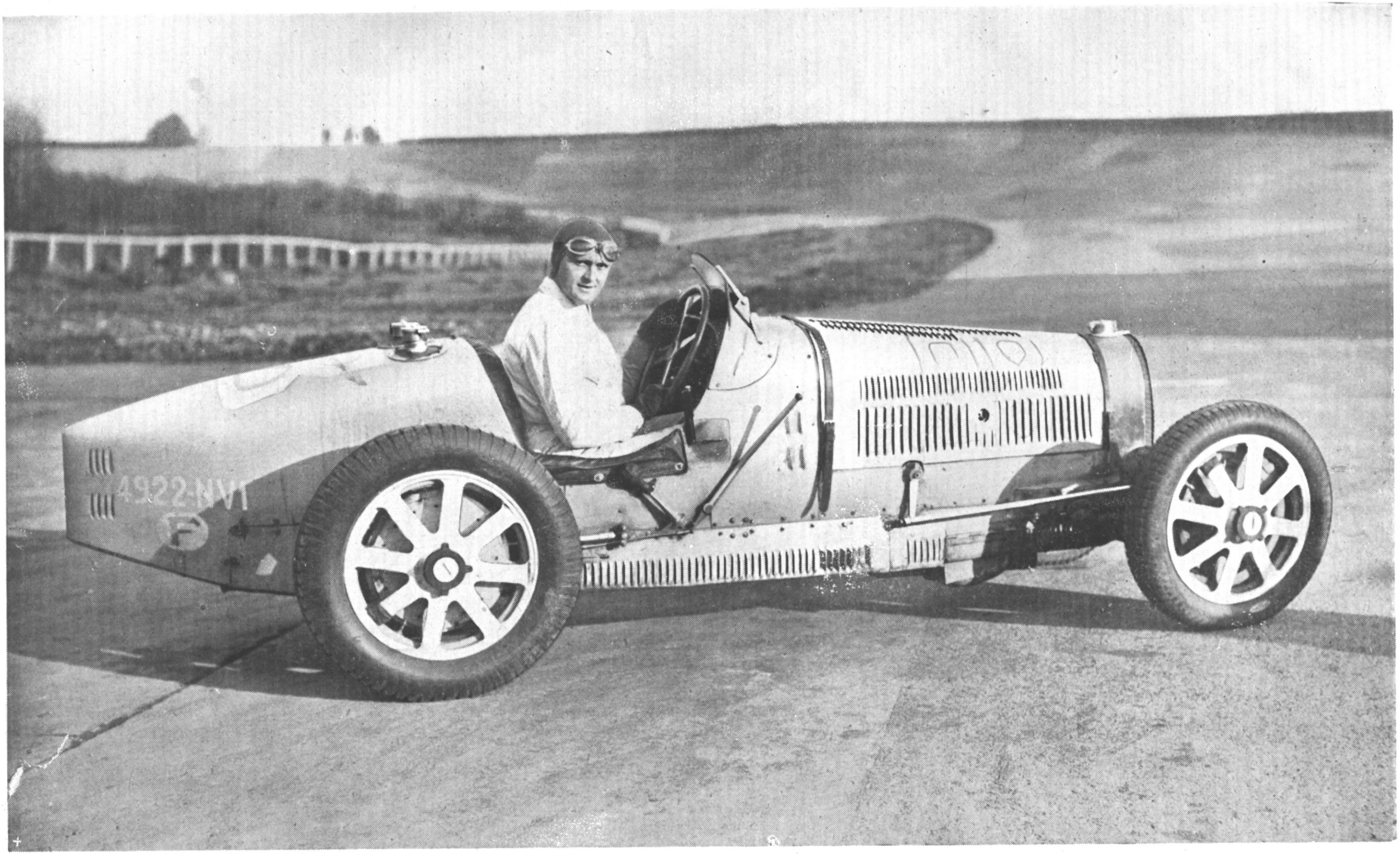


Plate XII

LE PUR SANG - L. Chiron at the wheel of the Type 51 Bugatti, an eight-cylinder, 2.3-litre, car developing 160 b.h.p., winner of the 1931 ten-hour French Grand Prix at Montlhéry with an average of 78.16 m.p.h. This type of car, and the Type 35 which it closely resembled, won thirty-three major road races in seven years - an unequalled record.

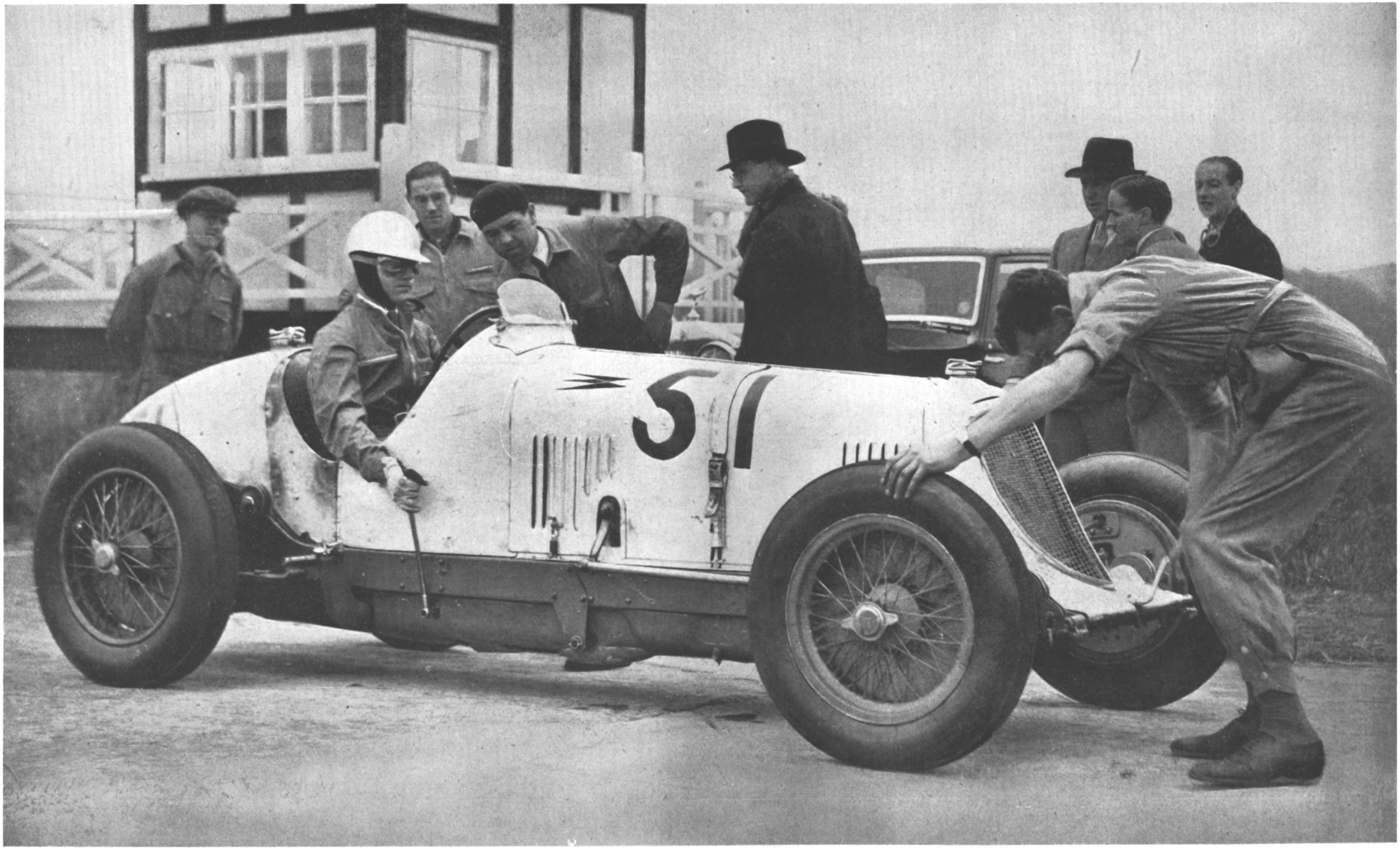


PLATE XIII

LAST OF THE LINE - The 1934 single-seater Maserati with 2.9-litre straight-eight engine represented (together with the corresponding Alfa Romeo) the highest development of the orthodox sprung chassis with rigid front and rear axles. The car shown developed 205 b.h.p. and was a direct development of a design initiated in 1930. This picture shows Whitney Straight about to break the International Class D flying kilometre record ot 136.98 m.p.h. in June 1934.

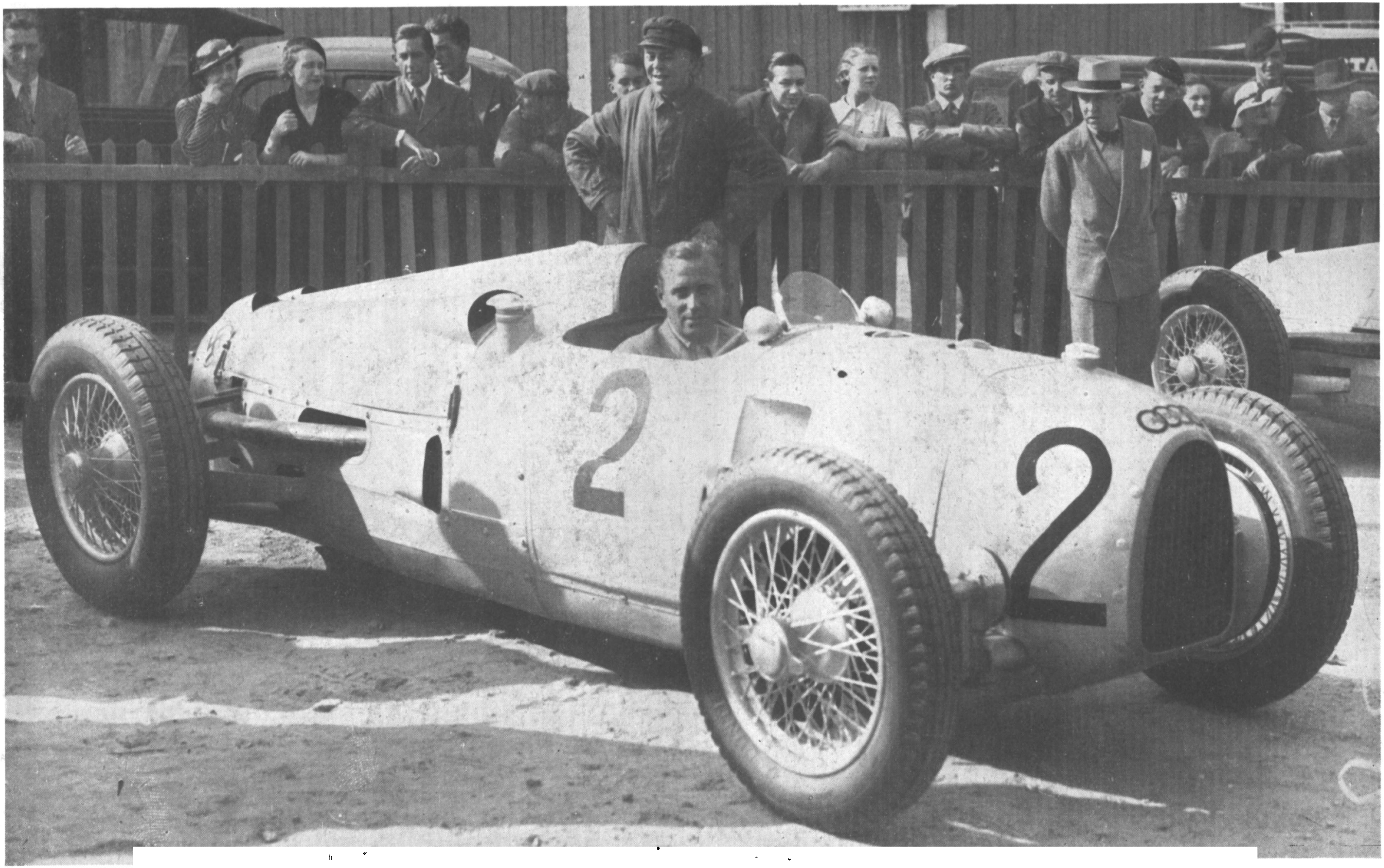


PLATE XIV

A SUCCESSFUL CHALLENGE - The Porsche-designed Auto-Union cars which appeared in 1934 embodied all-independent suspension tubular frame and rear mounting for the 4.36-litre, 295 h.p., V.16-cylinder supercharged engine. The car shown here is that driven by Fagioli in the 1934 Grand Prix de l'A.C.F. and despite many other unorthodox features, this model and the direct descendants thereof secured 17 victories in this and the ensuing three years.

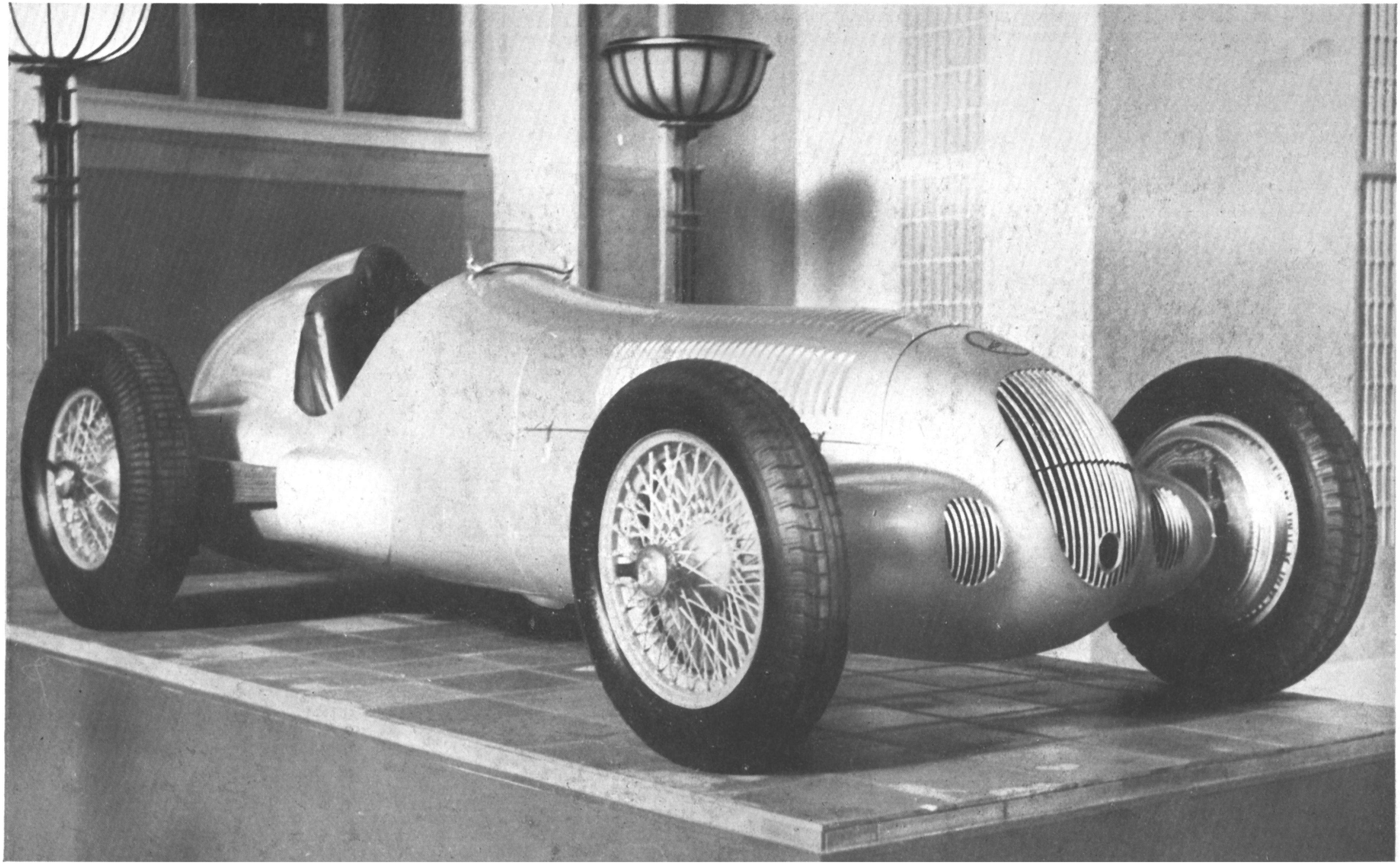


PLATE XV

MAXIMUM POWER - The I937 Mercedes-Benz built for the last year of the 750 kg. Formula had an eight-cylinder in-line 5.66-litre engine which at the peak of its development developed 646 b.h.p., the highest figure ever available in road racing. The chassis of the car was notable for the first use on a racing car of a de Dion type rear axle, and the tubular chassis frame combined light weight with new standards of stiffness. The lap speeds achieved by this car on the Berne, Brno, Donington, Monaco, Roosevelt and Tripoli circuits have remained unbeaten for 15 years.

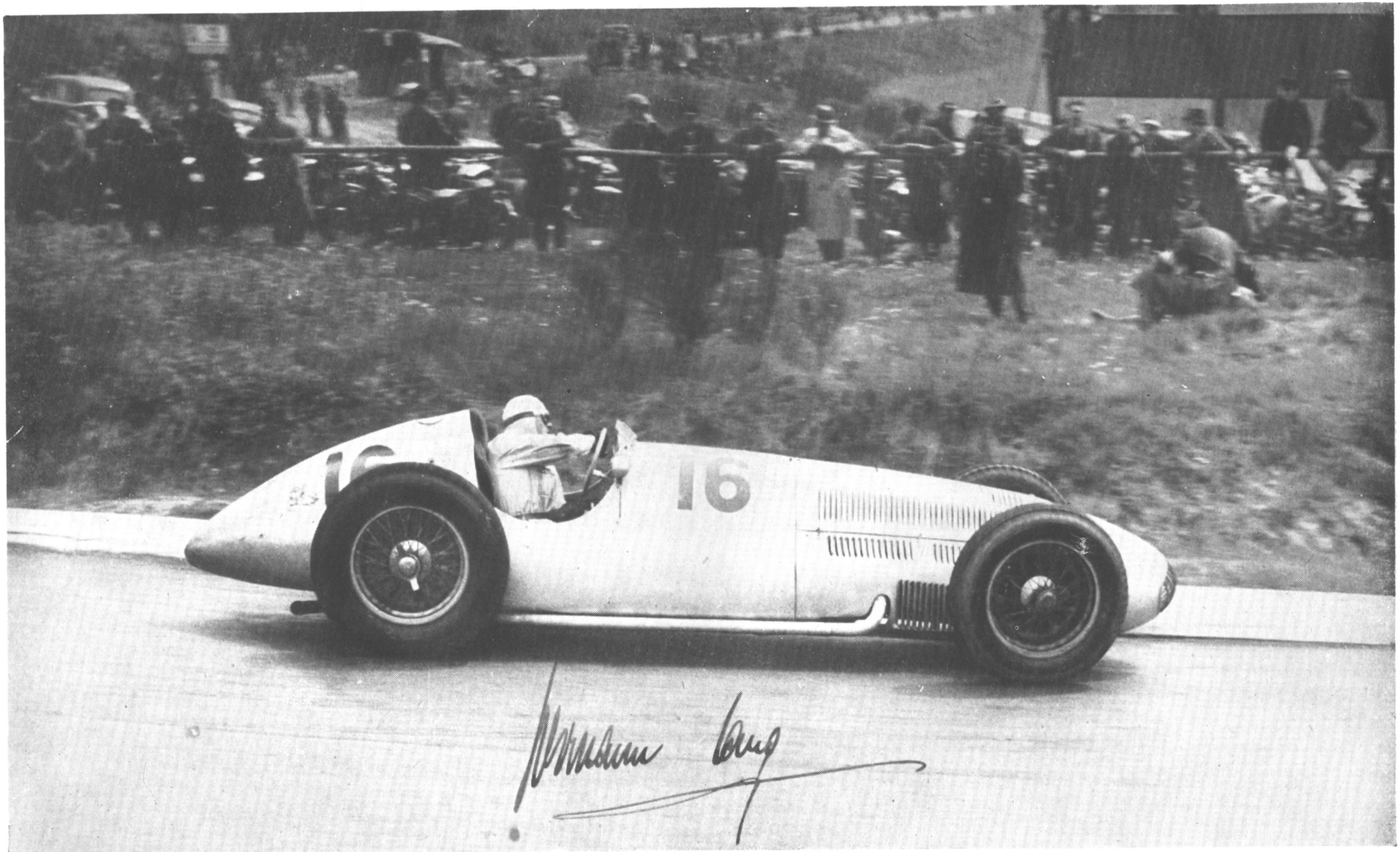


PLATE XVI

SUPREME SPEED - Lang on the twelve-cylinder, 490 h.h.p., 3-litre Mercedes-Benz with which in 1939 he made the fastest timed laps of four Grand Prix circuits with an astonishing peak of 117.5 m.p.h. in practice for the French Grand Prix at Rheims. During this same year he piloted the car to victory in the Belgian and Swiss Grands Prix and in the Eifel Races.

This event marked the second successive breakaway in organisation which had been effected in two years. In 1921 the replenishment depots became pits in name only, all equipment being kept at ground level with manual refuelling from cans or large jugs. In 1922 despatch of competitors in pairs was abandoned and Strasbourg spectators were the first to witness a mass start Grand Prix.

Despite their success in the previous year there were no American competitors amongst the nineteen entries (of which eighteen started), comprising teams from Fiat, Bugatti, Sunbeam, Ballot, Rolland-Pilain and Aston Martin, all of three cars except Bugatti who had four and Aston Martin who had two. The principal non-starter was Delage, who had constructed four-cylinder engines which were obviously deficient in power output, and it is interesting that despite the supremacy of the straight-eight power-unit during the 1921 season only two entries in 1922 embodied this construction -Rolland-Pilain and Bugatti. The former need not long detain us, as it was never a very successful design, although it embodied many ingenious mechanical features. The latter was a forerunner of a range of successful cars during the next decade. The crankshaft ran on three ball bearings, the cylinders were castings of two blocks of four, and a single overhead camshaft operated two inlet and one exhaust valve placed vertically in the cylinder head. Two carburetters were used, and it was claimed that the 60 x 88 mm. engine would give 90 h.p., although this probably was an exaggeration.,

The Ballots were four-cylinder catalogue sports models which had done quite well in the preceding Grand Prix and were, of course, of Henri design.

The Aston Martins also had four-cylinder engines, but had a swept volume of only l½-litres.

Both the Bugattis and the Ballots were fitted with egg-shaped bodies, and amongst the ingenious features of the former was a scheme for taking the exhaust out through the centre of the body. It was supposed to favour streamlining, but it made the interior of the car extremely hot.

The Fiats had engines which were scaled-down replicas of the 1921 3½-litre eight-cylinder models. The bore remained the same, 65 mm., but the stroke was reduced from 112 to 100 mm., giving a capacity of just under 2 litres. The general specification of the engine, with timing gears at the back, cylinder built from steel forgings with welded-on jackets, wide angle valves, and all-roller-bearing engine, was identical with the previous types, and the choice of six cylinders seems to have been dictated primarily by convenience and not by belief in the superiority of the number as compared to eight cylinders in a line.

As Ballot had decided to rest upon the laurels of the 3-litre " eights " and not to produce pure racing cars to meet the 2½-litre formula, Henri transferred to the Sunbeam Company, where he worked under the patronage of Louis Coatalen in producing an entirely new design. In this model the designer continued on the lines which had hitherto brought him and his followers so much success, but rather surprisingly he abandoned the straight-eight engine in favour of a four-cylinder unit with dimensions of 68 x 136 mm. This had an iron casting as cylinder block with four valves per cylinder inclined at a small angle. The crankshaft ran on ball bearings throughout with plain big-ends ; the two camshafts were driven by a train of timing gears from the front end of the engine ; the gearbox was built in unit and the brakes had mechanical servo action.

By reason of having a small piston area, long stroke and restricted r.p.m., the Sunbeams were beaten before they started, and, in fact, during the race at Strasbourg they were never in the same class as the Fiats. Their highest lap speed was approximately 78 m.p.h., whereas the Bugattis were able to average 80 m.p.h., and the best Fiat speed was 87.75 m.p.h. Nazzaro, driving this make, won easily at an average speed of 79.2 m.p.h. Rear axle troubles affected the other two cars of the team at the last moment and prevented them having a grand slam, and thus two Bugattis finished second and third.

Nine out of the eighteen starters had finished in the 3-litre race of 1921, but only four cars were running at the end of the 1922 race and two-thirds of the entry failed to get past half distance. Furthermore, the superiority of the Fiat cars was so great that Bugatti alone challenged in the other 2½-litre event held during 1922, viz. : the Italian Grand Prix, run on the newly constructed 6¼ miles Monza circuit. This race had in fact a record number of non-starters. Ballot, Benz, Bianchi, Delage, Mercedes, Rolland-Pilain and Talbot Darracq all decided that a Fiat victory was a foregone conclusion and forfeited their entry fees. Moreover, three out of four Bugattis failed to start owing to lack of tyres with the required rolling radius, and two Diattos retired at quarter distance, so that the Fiat team had a very hollow victory, Bordino winning at 86.89 m.p.h., and putting up a record lap of 91.3 m.p.h.

Looking at the season as a whole, one of the principal points of interest was the complete failure of the Henri-designed cars. He had been directly represented in the Sunbeam G.P. models, indirectly through Ballot, but by now the theories which he had successfully advocated for so long had out-lived their usefulness.

The technical features of the Henri period and the reasons for the sudden swing to radically differing types of construction are discussed in detail elsewhere in this book. So far as the story of Grand Prix racing is concerned it is significant to note that the 1922 2½-litre cars with atmospheric induction were amongst the slowest Grand Prix models to be built, for although benefiting by front brakes it is doubtful if they could hold their own with, say, the 1908 cars either in respect of maximum speed or acceleration.

As so often occurs, however, a low level in design and performance was the prelude to a great step forward. Already racing cars had been built and run with supercharged induction systems. The general application of blowing to the Grand Prix car was to effect a dramatic step up in performance during the next five years, and was already foreshadowed by the entry of two 1½-litre four-cylinder supercharged Mercedes cars in the 1922 Targa Florio. Following on this development a team of three blown Mercedes of 2-litre capacity ran in the 1923 Indianapolis race on May 30th and a team of eight-cylinder blown Fiats appeared in the French Grand Prix two months later.

The 500 Mile Sweepstake at Indianapolis was won by an eight-cylinder Miller-designed H.C.S. at 90.95 m.p.h. The race attracted eight European cars, five Bugattis and three Mercedes. The former were similar to the 1922 (Strasbourg) Grand Prix cars, but they were now fitted with very narrow single-seater bodies and provided with first-class drivers. However, they were never at all prominent ; the highest position occupied being fifth and the only one to finish took ninth place.

The supercharged Mercedes cars were far more formidable. The design was by no means a simple enlargement of the 1922 1½-litre Targa Florio model but was an

entirely new type with a four-cylinder (70 x 129 mm.) engine from which 120 b.h.p. at 4,500 r.p.m. was claimed, maximum speed being estimated at 118 m.p.h. In the U.S.A. these cars were handicapped by poor pit work and inadequate training for the drivers, but, nevertheless, one car driven by Werner was third for many miles, finishing tenth after experiencing valve trouble. Of the other two in the team one came in eighth, and the third, driven by Lautenschlager in his last race, hit the wall at the end of fourteen laps. The driver was uninjured but this was a sad finish to the racing career of a man who had won the French Grand Prix twice in two starts.

The German concerns were debarred from entering the French Grand Prix which was held at Tours in July, but no less than five other constructors prepared entirely new designs for this event, a fact which shows very clearly what a deep impression the new Fiat mode of construction had made on engineers in the previous year. For the third successive year eighteen cars were entered, there being teams from Bugatti, Delage, Fiat, Rolland-Pilain and Voisin. Bugatti and Voisin each entered four cars and Delage one, and all the entrants showed a marked diversity in design, only Rolland-Pilain running cars which had been constructed the previous year.

Bugatti kept the same engine as previously, but had ultra-short wheelbase chassis with tank type streamlined coachwork. Voisin, also, had carefully calculated bodies of good aerodynamic form. Delage returned to racing with a car designed by M. Plancton and built in only four months, orthodox so far as the chassis was concerned, but with a twelve-cylinder engine potentially capable of a very high r.p.m., and road speed, the stroke being only 80 mm. and the bore a mere 51.3 mm.

Between the trials prior to the 1922 French Grand Prix and the Italian Grand Prix in September, the output of the six-cylinder type 404 Fiat was raised from 92 b.h.p. at 4,500 r.p.m. to 112 b.h.p. at 5,000 r.p.m., and there was apparently but small incentive to change a proved design. But on Fornaca’s insistence on greater power this engine was discarded in 1923 and replaced by the type 405 designed by Zerbi and Cavelli, this being a straight-eight with bore and stroke of 60 x 87.5 mm. and, most important, with the carburetters fed by pressure air from a displacement type blower. As first built, 130 h.p. was realised at 5,500 r.p.m.

Louis Coatalen followed once again his policy of buying up the best brains from his rivals. During the previous winter he secured the services of Bertarione from Fiat, and it is, therefore, not surprising that the 1923 Sunbeam engines showed a very strong resemblance to the previous Turin products. In point of fact the 1923 Sunbeam engine was almost identical to that of the 1922 Fiat, except that 2 mm. were added to the bore and 6 mm. taken from the stroke (giving dimensions 67 x 94 mm.), whilst the exhaust valve was made larger than the inlet valve. The external appearance of the car was very “ Fiat-like” although the chassis was basically the 1922 type designed by Henri.

The contest between these two makes was close, for a Sunbeam was second at five laps, first at ten laps, first at twenty laps, second at thirty laps, and Segrave finally won on the thirty-fifth lap. Fiats, on the other hand, were first at five laps, second at ten laps, first at twenty laps and first at thirty laps. No Fiat finished, all of them going out with various mechanical troubles, including break-up of the rather primitive vane type of blower which is more fully described elsewhere. Sunbeams were also second and fourth, Bugatti running third, twenty-five minutes behind the winner.

The Bugatti drivers were handicapped by the odd proportion of wheelbase and track chosen by their designer, which was 6 ft. 6 in. and 3 ft. 3 in. respectively, and this made them very hard to hold on the straight, although they were quick through the corners.

For the Italian Grand Prix entries were made by Alfa Romeo, Benz, Fiat, Voisin, Rolland Pilains, and Miller. The Alfa Romeo team were withdrawn before the start following an accident in which one of the drivers, Sivocci, was killed. The cars used were supercharged six-cylinder types with the designation P.l. Practice for this event was their first and last in public.

The so-called " Tropfwagen " Benz cars had six-cylinder engines mounted behind the driver and ahead of the rear axle, and were of markedly pear-drop shape with external radiators mounted on struts behind the driver's head. These cars exerted no immediate influence, but, as will be narrated in due course, led directly to the production in 1934 of the Auto-Union " P-wagen."

The Millers were Indianapolis type cars, unsupercharged, and gravely handicapped by inadequate transmission and braking systems.

In the two months that had elapsed since the French Grand Prix the Fiats had been fitted with Roots type blowers and they now showed their quality in no mean fashion. Bordino led up to half distance, a staggering effort for he had broken his arm in practice and had to drive with one hand, the mechanic changing gear. He was forced to retire through physical exhaustion and Salamano and Nazzaro finished first and second, with a Miller, driven by Jimmy Murphy (the 1921 French Grand Prix winner), third, five minutes behind. Benz ran fourth and fifth. The winning speed was 91.06 m.p.h. and Fiat also raised the lap record for the Monza track to 99.8 m.p.h. They were thus 5.6 m.p.h. faster over the race distance and over 7 m.p.h. faster on a lap than the six-cylinder atmospheric induction cars of the previous year.

The Italian Grand Prix of 1923 was the first international race to be won by a supercharged car and from then until 1939 only one event of this status (the 1925 Targa Florio) was won without a blower, except on those occasions when supercharging has been proscribed by the regulations.

The following year Indianapolis was innocent of European entries and from this time forward American and European types of racing car have developed on such widely differing lines that a study of the former steps out of the frame of reference of this work.

In Europe the racing year of 1924 opened with the Targa Florio, which was won by a 2-litre supercharged Mercedes of the type which had run in the previous year's Indianapolis. During the intervening twelve months it had, however, been improved in detail by Dr. Porsche who had just become chief engineer to Mercedes after fifteen highly successful years with the Austro-Daimler Company.

After the withdrawal of the P.l Alfa Romeos at Monza this type was scrapped and an entirely new design developed under the supervision of Jano. This, the P.2 model, had a straight-eight engine with welded steel cylinders in four blocks of two and a bore and stroke of 61 x 85 mm. Both crankshaft and big ends ran on roller bearings and the Roots type supercharger was mounted on the ends of the crankcase and provided with optional gear ratios so that the boost could be changed quickly. A blower supplied pressure air through a finned pipe to a carburetter mounted at the back

of the engine. Not only in respect of engine design but also in both body work and general external appearance the car followed the conventions established by Fiat in 1922.

Following the Targa Florio a race was held over a long circuit near Cremona in Italy. The P.2 Alfas were entered for this and won easily at 98.3 m.p.h., one car, driven by Ascari, being timed to cover 10 kilometres at an average speed of 123 m.p.h. This was clear enough proof that the young concern would be a formidable contender for honours in the French Grand Prix run at Lyons on August 3rd, for which twenty-two cars were entered. There were teams from Alfa Romeo, Bugatti, Delage, Fiat, Miller, Sunbeam and Schmidt.

The Alfa Romeo, Delage and Fiat designs all derived from the 1923 types but embodied substantial modifications. Externally, the most notable change was by Bugatti, who used an engine of 1923 dimensions but which was improved in detail and installed in an entirely new chassis remarkable for the use of light alloy wheels which were cast and formed in one with the brake drums. This was the first of the famous Type 35 models. The Delage also used a similar engine to that employed for the previous year but both the chassis and the body had been very extensively redesigned by Lory, resulting in an entirely new appearance. Fiat, on the other hand, were externally similar to 1923 but the engine retained the Roots blower used for the Italian Grand Prix of the previous September and now developed 146 h.p. at 5,500 r.p.m. with a slightly modified cylinder head.

The Miller was a private entry of an Indianapolis type car. The Schmid was a six-cylinder with cuff valves. Sunbeam was the only other car not adhering to the straight-eight principle. This team were using the previous year’s engines which, with Roots’ blowers added, developed 138 b.h.p. A rather longer and improved chassis included torque tube drive and a four-speed gearbox. They were clearly so superior to any other makes that Alfas, who considered themselves the likely runners-up, approached the Sunbeam team manager with a suggestion that if he would permit Alfas to occupy second and third position they would gladly let Sunbeams take first place without pressing any of the cars too hard.

This “ offer ” was probably made with a light heart over a mutual glass of wine ; it is certain that Sunbeams went to the line confident of a second successive victory in Grand Prix racing, but this was not to be. The night before the race they were visited by the Bosch Company, who exclaimed upon the burnt contact-breaker covers of the magnetos, which were placed at the rear of the engine facing outwards towards the exhaust pipe. These particular instruments had remained untouched since the previous year, and no doubt the addition of the blower caused the piping to get much hotter and caused the burning to start. Bosch mechanics made a replacement with some magnetos of the latest type that had just arrived from Stuttgart.

During the race the Sunbeams suffered from constant misfiring. Their superior speed was confirmed by unofficial timing during the race, which gave Sunbeam 130 m.p.h., Alfa-Romeo 124 m.p.h., and Delage, running unsupercharged, 114 m.p.h., but nobody could account for the irregular running of the cars which constantly held them back. Sunbeam’s ill-luck thus gave Alfa Romeo the rare distinction of winning the French Grand Prix with their first entry for the event at 71.0 m.p.h. Nicola Romeo and Ing. Jano must have felt well satisfied, also Molino, Bazzi, and the young engineers who were largely responsible for this remarkable car. Eight years had to

pass before Alfa Romeo won the A.C.F. classic again, although they had great success in other events.

The Bugattis suffered badly from tyre trouble and finished seventh and eighth, whilst the Fiats at the end of the tenth lap were running second, tenth, nineteenth, and twentieth, a sad fall from grace after their predominance in the previous year. When Bordino retired with defective front brakes their four cars ceased to be effective challengers ; for although Nazzaro survived until the twentieth lap, he also went out with brake trouble, he was then lying last.

In the middle of the night following the race the Sunbeam development engineer, Captain Jack Irving, leapt from his couch, rushed to the sheds, put back the old magnetos and the trouble vanished. By such a small incident were the Wolverhampton Company deprived of the rare honour of winning the French Grand Prix for two successive years.

In the Italian Grand Prix at Monza no Fiats were entered, and four Alfa Romeos were so much faster than any other car that when their slowest model finished, the next car, a Schmidt, was flagged off ten laps behind. The winner, Ascari, put up the lap record to 104.24 m.p.h., and had a winning average of 98.76 m.p.h. This means that the P.2 Alfa lap speed was 5.64 m.p.h. better than the supercharged 2-litre Fiat and 12 m.p.h. faster than the 1922 unsupercharged 2-litre Fiat, a remarkable tribute to the rapid progress made in racing car design.

Just previously to this Sunbeams secured compensation for their French Grand Prix disappointment by winning the Spanish Grand Prix, Segrave coming in first at 64.12 m.p.h., a minute and a half ahead of a Bugatti, with a Delage running third, Bugatti put up the best lap at an average of 71.7 m.p.h.

Although still debarred from French and Belgian races, German cars were amongst those invited to compete in Spanish and Italian events, and Mercedes accordingly ran the two 2-litre four-cylinder cars (the re-designed Porsche Indianapolis type) at San Sebastian. At Monza they appeared with two wholly Porsche designed straight-eights with engines developing about 170 b.h.p., but the chassis design of this latter type was so inferior that they had no success, indeed during the Monza race Count Louis Zborowski met his death when driving one of these models.

1925 was the last year for the 2-litre limit cars and during the whole of the season designers were pre-occupied in devising 1½-litre models for the ensuing year. This explains why no new designs were prepared, and, although for the first time in the history of European racing, regulations specified that the cars were to start with only the driver aboard, a two-seater body was still required.

As one might expect, no new constructor came forward with a 2-litre car and only Louis Delage embodied any substantial modifications to the existing 1924 designs. He having previously pinned his faith entirely to the virtues of a large piston area now decided to seek additional b.h.p. with the aid of forced induction and changed the body and bonnet layout for the second time since 1923.

At the beginning of the year Bugatti scored the last win for an unblown type over the Targa Florio circuit. Then, and rather surprisingly early in the year, came the European Grand Prix run by the Automobile Club de Belgique on the Spa Circuit. In this race the new supercharged Delages competed with the now well established P.2 Alfa Romeos, but all retired with a most unusual trouble. The normal blow-off valves

on the pressure side of the manifold were not fitted and popping back when accelerating built up large pressures in the inlet system relieved by blowing open the inlet valves. These then fouled the exhaust valves with resultant damage. In consequence Alfas were first and second, Ascari averaging 74.56 m.p.h.

The French Grand Prix represented a notable change with tradition. Since its inception it had always been run on closed road circuits, but this year it was staged on the Montlhéry circuit, one having all the features of a road, but artificially built and without the hazards of the Route Nationale. Entries were received from Alfa Romeo, Bugatti, Delage and Sunbeam.

The Alfa Romeo and Delage cars were run in their Belgian Grand Prix form, but the latter was now fitted with the usual blow-off valves in the inlet manifolding. Both cars were giving between 160 and 190 b.h.p. and were thus much faster than the competing Bugatti and Sunbeams and the three British cars were virtually unchanged from the previous year and were developing not more than 140 to 150 b.h.p., Bugatti clung to the belief that by attention to chassis detail and light weight he could successfully compete with an unsupercharged engine giving around 100 b.h.p.

In the opening laps the P2 Alfa Romeos of Ascari and Campari ran in the first two positions, followed by two Delages. On his eleventh lap Ascari covered the circuit at an average of 80 m.p.h., but shortly after quarter distance his car left the road, overturned and he was killed, and although Campari continued to hold the lead up to half distance (at which point he had averaged 75.5 m.p.h.) his car was withdrawn as a mark of respect. The lead was then taken by the Delage, driven by Benoist and Divo, and they continued to hold it until the end, winning at 69.7 m.p.h., with another Delage second. Divo broke the lap record at 80.3 m.p.h. Sunbeam was third. Bugatti cars tiled fourth, fifth, sixth, seventh and eighth positions with an entry of three works and two privately owned cars.

Following this the Italian Grand Prix was run again at Monza, in which race for some reason Delage decided not to enter. The Alfa Romeos had no serious opposition from two Duesenbergs and a Bugatti, finishing first and second at 94.76 m.p.h. The best Duesenberg came in fourth and showed its speed by putting up fastest lap at 103.2 m.p.h., barely 1 m.p.h. slower than the Alfa record put up the previous year. However, the by now usual U.S.A. troubles of brakes and gears prevented the car from really pushing the winners over the whole distance and this accounts for the reduction in overall average.

1925 ended with the Spanish Grand Prix for which Alfa Romeo did not enter, thus providing Delage with an easy win at 76.4 m.p.h.

It will be noticed that Fiat took no part in the 1925 racing season, but their star driver, Bordino, took a 1924 model to the U.S.A. He ran at Indianapolis but finished last after many pit stops for sparking plugs. Later in the year the car was timed to cover 25 miles on a board track at Culver City at an average speed of 133.7 m.p.h.

These four racing seasons undoubtedly represent the zenith of Italian technical supremacy. They are particularly notable for startling increases in engine power and maximum road speed. Subsequent cars, by virtue of better brakes and improved road holding, improved on the performance of these 2-litre models on some circuits, but so far as maximum speed was concerned, it was ten years before racing cars became much faster.

CHAPTER EIGHT

Cost Versus Result

RACING STATISTICS 1926-27

Date	*Event*	*Course*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Lap Speed*
27/6/26	French G.P.	Miramas	J. Goux	Bugatti	68.2	79.4
18/7/26	European G.P.	San Sebastian	J. Goux	Bugatti	65.5	81.5
7/8/26	English G.P.	Brooklands with Chicanes	R. Senechal L. Wagner	Delage	71.61	—
7/8/26	„	„	H. O. D. Segrave	Talbot	—	85
5/9/26	Italian G.P.	Monza	“ Sabipa ”	Bugatti	85.87	—
5/9/26	,,	,,	M. Costantini	Bugatti	—	98.3
3/7/27	French G.P.	Montlhéry	R. Benoist	Delage	77.24	81.43*
31/7/27	Spanish G.P.	San Sebastian	R. Benoist	Delage	80.52	85.41*
4/9/27	European G.P.	Monza	R. Benoist	Delage	90.04	94.31
4/9/27	Milan G.P.	Monza	P. Bordino	Fiat	94.57	96.59
1/10/27	English G.P.	Brooklands with Chicanes	R. Benoist	Delage	85.59	—

THE “ 130 m.p.h. plus ” maximum speed of the 1925 2-litre cars taxed the drivers to the uttermost. In an endeavour to limit the possible casualties the A.I.A.C.R. took a notable step when they altered the regulations for 1925 so that a car started with only the driver aboard, although the use of a two-seater body was enforced. The regulations on this point were maintained for 1926, in which year, however, the minimum weight was reduced from 650 Kg. (12.8 cwt.) to 600 Kg. (11.8 cwt.). At the same time with a view to reducing maximum speeds to within the road holding capabilities of the car, engine capacity was brought down to 1½-litres, thus bringing Grand Prix cars on to the level of what had, since 1921, been considered the Voiturette class.

When this combination of capacity and weight was announced in 1925 it was condemned by drivers and constructors alike. Everyone was agreed that the existing 2-litre cars were too lightly constructed and the prospect of a reduction in weight, coupled with a maintenance of speed due to enhanced engine efficiency, led to predictions of dire disaster. Indeed, responsible persons claimed that less than half a dozen drivers could take full advantage of the existing 2-litre cars and they considered that new, and lighter, 1½-litre models would be even more difficult to handle.

These criticisms were based on the assumption that designers would do all in their power to reach the minimum weight figure. In point of fact they did no such thing, practically all the cars scaling between 2 and 3 cwts. over the minimum which, in any event, was raised to 13.76 cwt. in 1927.

Racing car designers were, of course, thoroughly familiar with the problems of 1½-litre models, many of which had been closely related in design to the larger types. It was, therefore, thought that there would be no particular difficulty in providing cars to the new formula, and, as has been seen in the previous chapter, in 1925 manufacturers supported racing in large numbers. Works teams had issued from Alfa Romeo, Bugatti, Delage, Fiat, Rolland-Pilain factories, as well as from Benz, Schmid and Mercedes which had made for exceedingly interesting racing.

In 1926 the promise of a 1½-litre formula was even more satisfactory. Although Alfa Romeo announced their intention of retiring from the field, most of the other companies were probable entrants, and, in addition, new contenders were to be expected from Alvis and Thomas in England, O.M. in Italy, and Sima-Violet in France.

This being so, the A.C.F. looked forward with a pardonable degree of optimism to the running of the French Grand Prix at Miramas at the end of June. Alas for their hopes ! Out of all these possible starters Bugatti alone was ready to race, and he secured a complete walk-over. A unique occasion, one must think, not only because of the absence of other competitors, but because it must have been the only time when Bugatti was ready and the other people were not ! It was, however, not so much design as construction that was at fault, for much earlier in the year there had been full descriptions of a variety of cars in course of development.

Of the newcomers, Alvis had an eight-cylinder front-wheel drive car on the stocks, the Thomas Special utilised the same number of cylinders with conventional rear drive, and the Sima-Violet was a two-stroke design and built by a man who had had a great deal of experience with this type in 750 c.c. events. Fiat also built a supercharged two-stroke on which a great deal of work was done but which never appeared in competition.

The real struggle in the two years reviewed in this chapter was between Bugatti, Talbot and Delage. In 1926 Bugatti ran supercharged versions of 1925 Grand Prix cars with cylinders reduced to 52 mm. to bring the capacity inside the limit. Talbot (given this name quite arbitrarily as a member of the Sunbeam Talbot Darracq group) was an entirely new design. The eight-cylinders were made up in two blocks of four, with the characteristic Bertarione welded-up construction. The crankshaft was also made in two pieces and ran on roller bearings throughout, whilst the whole engine was offset from the centre line of the chassis, enabling the driver to sit really low down on the offside of the car.

The frame was an excellent piece of work, stoutly cross braced and immensely stiff as a beam, being made from a double length of channel with suitable vertical spacing members, each side member being pressed out as one piece ; in other words, it was rather like the Lancia " Lambda " frame on a small scale. The front axle was hollow and in two pieces, with a flanged joint in the centre.

A four-speed gearbox in unit with the engine transmitted power to a double reduction in the rear axle, the propeller shaft thus being exceptionally low. In order to comply with the regulations requiring the possibility of a passenger seat, the driver was markedly offset to the right.

The Delage chassis offered a remarkable contrast. As on the Talbot the engine and gearbox were in one unit, but on the Delage this was of abnormal length and so mounted in the frame that it contributed nothing to the torsional stiffness of the car.

The engine, designed by M. Lory, was a direct development from the twelve cylinder used on the previous year's 2-litre cars. It was a straight-eight, but, nevertheless, the basic design concept was very similar, including the use of an iron casting for the block, the proportion, location and drive of the valves, and the details of the crankshaft and rods. Cylinder dimensions were 57.5 x 75 mm. (as against 51.3 x 80 mm.), and the induction arrangements included two superchargers mounted centrally on the near side of the crankcase. They were driven by a pair of gear wheels like those employed on the Monoposto Alfa Romeo of later time, but mounted on a long shaft which ran forward inside the crankcase to pick up with the timing gears on the front end of the engine. Each blower served four cylinders and the engine was set slightly across the frame, the transmission line extending along this angle so that the crown wheel and pinion were appreciably offset toward the near side of the car. Once again, the purpose was to lower the driver and so reduce the frontal area. A five-speed gearbox was employed, and, unlike the Talbot, the frame was exceedingly light and flexible. The Delage brakes were put on through the medium of a friction servo device driven off the rear end of the gearbox, but the Talbot had self-servo shoes in the brake drums.

The Delage made its first appearance in the European Grand Prix at San Sebastian, in July, and showed itself slightly superior in speed to the Bugattis, fresh from their French Grand Prix victory. This notwithstanding, Bugatti came home first, as at one time and another all the Delage cars were brought to stop for varying periods of time. Owing to the disposition of the superchargers on the near side of the car the exhaust pipe came along the off side, and the offtake pipe of No. 8 cylinder formed a tube of red-hot metal but a few inches from the pedals. The effect, when combined with strong Spanish sun, may well be imagined, and it is certain that this defect cost Delage the race.

The Talbots appeared on the scene in the first of the English Grands Prix which have been run by the R.A.C., and the event showed that they were by no means in a fit state to race. On one of them the front axle broke in the first lap, and although Segrave led for ten laps, and actually made the fastest lap of the day, he eventually went out, probably with valve trouble. The third car also suffered engine trouble before the race was over.

Thus, late in the year it was possible to put Talbot, Delage and Bugatti in an ascending order of reliability and a descending order of speed. One might have hoped for a Grand Finale with every car at its best in the Italian Grand Prix, but this was not to be. Bugatti ran unchallenged, won the race, made fastest lap, and secured the European Championship of 1926.

In 1927, the competitors who had fought out a triangular contest in 1926 were again fighting each other. But whereas the Talbot and Bugatti cars ran with comparatively small changes (albeit the Bugattis had larger radiators and superchargers, new engine dimensions of 60 x 66 mm., and were certainly faster than the 1926 models), Delage incorporated radical " mods " as a result of his unhappy experiences in the previous year's events. The cylinder block was turned back to front, as it were, and the exhaust system shifted to the near side of the car where it was well out of the way. This obviously made it impossible to keep the twin blowers in the centre of the crankcase ; they were therefore deleted and a small plate covered up the hole previously made by the drive. A single supercharger, using the same rotor forms as previously, and therefore of rather abnormal length, was now mounted at the front

of the engine, raised rather high so as to give ample clearance for the front axle and the chassis. The steering connections were stiffened up considerably, and over half a hundredweight was added to the weight of the car. With these changes the Delage proved quite invincible, and, in fact, for a decade no one was able to, produce a more powerful engine of this size. It stands to this day as a high-water mark of efficiency if one takes blower pressures into account.

In no event in 1927 did all the cars reach the starting line. For example, at the French Grand Prix, run at Montlhéry on July 3rd, Bugatti was a non-starter, leaving the race virtually as a straight fight between Talbot and Delage. The former cars now had complete new front brake and axle gear, and one driven by Divo led on the first lap, the other member of the team being third with a Delage second. On his fifth lap Williams, driving a Talbot, got very near to the lap record put up by the 2-litre cars by averaging 80.27 m.p.h., and the absolute record was, in fact, broken on the tenth lap by Benoist, who achieved 81.43 m.p.h. on a Delage. By twenty-five laps both the Talbots were experiencing mechanical troubles and from thirty laps onwards Delage were never displaced from the first two positions, holding the first three from the forty-third lap onwards. Benoist secured an easy victory, averaging 77.29 m.p.h. for 263.18 miles, the Talbot driven by Williams, finishing fourth, 39 minutes after the winner had received the checkered flag.

After this failure the Talbot cars made no further appearance as a works sponsored team, but in the Spanish Grand Prix Bugatti returned to the field on a course where the road holding capabilities of his car offered a good offset to deficiency in engine output and enabled Materassi to keep the lead until nine laps from the end. He then ran off the road, leaving his team mate, Chiron, second. With only four laps to go he in turn met with mechanical trouble and this gave Benoist on a Delage a relatively easy win at 80.52 m.p.h.

For some reason Bugatti then decided that he would not compete in the European Grand Prix run at Monza in September, and Delage considered his position so secure that he entered only one car with which Benoist made the fastest lap at 94.31 m.p.h. and averaged 90.04 m.p.h. for fifty laps of the long circuit on a wet track. The only serious competitors were a Duesenberg and two front-drive Millers, entered as Cooper Specials. One of the latter finished third at 77.02 m.p.h., and although they showed speed on occasion the American cars all suffered from poor brakes, inadequate three-speed transmission systems, and the inferior low speed torque characteristic of the centrifugal type of blower. Since their win in the 1921 French Grand Prix, American engineers had concentrated entirely on board and brick track cars designed for flat out running, in which field they were no mean performers. A 1½-litre Miller averaged 116.58 m.p.h. for 200 miles and 123.14 m.p.h. for 120 miles in 1926, and in 1927 a similar car averaged 130.05 m.p.h. on the Atlantic City board track for 200 miles. There can be no doubt that the Coopers running in the Grand Prix were as fast flat out as anything on the circuit, but neither they nor the Delage made the fastest Monza time in 1927. The Milan Grand Prix was run on the same day and over the same circuit as the European Grand Prix and was won by Fiat, making their sole appearance in 1927 (and their last entry in Grand Prix racing) with a remarkable twelve-cylinder car having two geared crankshafts and a bore and stroke of 60 x 63 mm. Bordino driving this car won a heat at 92.88 m.p.h. and then engaged in a great struggle in the final over 50 kilometres with Campari driving a 2-litre " P2 " Alfa Romeo. The latter was unable

to reproduce its 1924 form and finished 48 secs. behind the Fiat, which averaged 94.57 m.p.h. for the race and lapped at 96.59 m.p.h. in the rain.

These results make it appear that the Fiat was definitely a faster car than the Delage, but it must be remembered that the former ran over fifty laps and the latter was asked to cover only five. Moreover, the value of these average speed figures in establishing the relative ability of the eight-cylinder Delage and the twelve-cylinder Fiat is dubious since the best lap of both of them was below that of the relatively slow 1926 l½-litre Bugatti on which Costantini had lapped at over 98 m.p.h. on a dry track in the previous year’s race.

As, however, the Fiat engine gave between 175 and 187 h.p. at 7,500 to 8,500 r.p.m., it is reasonable to conclude that it was not only the most powerful but also the fastest of all cars built under the l½-litre formula and it is a great pity that there was no opportunity of confirming this belief in the race held four weeks later.

The second English Grand Prix, held on October lst, was the last race of the 1927 season and thus the finale of the l½-litre formula. The Duesenberg which had run at Monza was absent owing to transmission troubles, a Fiat team was scratched owing to the pre-occupation of the works with the Schneider Trophy Seaplane Race, and a front drive eight-cylinder Alvis broke a piston in practice. The only challengers to Bugatti and Delage remaining were two eight-cylinder Thomas cars, but neither of these ran at all well, so that the race became entirely a competition between two French constructors. Competition, however, is too strong a word for this race as the Delage team experienced no difficulty in keeping far ahead of their rivals, Benoist finishing first at 85.59 m.p.h.

It must be conceded that from a competitive viewpoint the l½-litre formula was a failure. By contrast it was a brilliant technical success, not only in continuing the remarkable progress made in the previous three years in the specific output of engines, but also by developing chassis with low centre of gravity and small frontal area as a consequence of offset single seats. These improvements were, however, only obtained by what was at the time an altogether unwarrantable expense. Competition in the 1914 French Grand Prix, the winning of which by itself made a successful racing season, involved an expenditure of £10,000 to £15,000. By 1925 the cost of maintaining a team of three racing cars through a number of events had risen to at least £40,000 even when full overheads were not charged upon machine-shop work, etc. This figure was undoubtedly exceeded with the 1½-litre cars owing to their far more delicate construction, while, simultaneously, the commercial value of racing declined. The beginning of popular motoring in Europe marked the end of the time when sales to the general public were substantially affected by racing successes. And so after weighing with mounting expenditure on the one hand, and diminishing returns on the other, the manufacturers decided one after another that the time had come to withdraw from the manufacture of special cars and the entry of works teams. Thus, within two years Grand Prix racing fell from one of its recurrent peaks to an absolute rock-bottom.

CHAPTER NINE

Low Water

RACING STATISTICS 1928-30

Date	*Event*	*Course*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Lap Speed (Rc'd*)*
22/4/28	Bordino Prize	Alessandria	T. Nuvolari	Bugatti	63.45	—
,,	,,	,,	E. Materassi	Talbot		64.3*
6/5/28	Targa Florio	Short Madonie	A. Diva	Bugatti	45.65	—
6/5/28	Targa Florio	Short Madonie	L. Chiron	Bugatti	—	46.2
10/6/28	Rome G.P.	Trefontana	L. Chiron	Bugatti	78.55	80.4
24/6/28	Cremona Prize	Cir. of Cremona	L. Arcangeli	Talbot	101.31	—
,,	,, ,,	,, ,,	G. Campari	Alfa Romeo	—	108.6*
5/7/28	Marne G.P.	Rheims	L. Chiron	Bugatti	82.5	91.4*
15/7/28	German G.P.	Nürburg	R. Caracciola	Mercedes	64.6	69.34*
28/7/28	San Sebastian G.P.	San Sebastian	L. Chiron	Bugatti	80.58	88.25*
19/8/28	Montenero Prize	Montenero	E. Materassi	Talbot	52.77	—
	,,	,,	T. Nuvolari	Bugatti	—	53.8*
9/9/28	European G.P.	Monza	L. Chiron	Bugatti	99.4	—
919128	,,	,,	L. Arcangeli	Talbot	—	103.2
14/4/29	Monaco G.P.	Monaco	W. Williams	Bugatti	50.23	52.7*
21/4/29	Bordino Prize	Alessandria	A. Varzi	Alfa Romeo	68.24	68.6*
5/5/29	Targa Florio	Short Madonie	A. Diva	Bugatti	46.21	—
5/5/29	Targa Florio	Short Madonie	F. Minoia	Bugatti	—	47.3*
26/5/29	Rome G.P.	Trefontana	A. Varzi	Alfa Romeo	80.2	—
30/6/29	French G.P.	Le Mans	W. Williams	Bugatti	82.66	—
1/7/29	Cremona Prize	Cremona	A. Brilli-Peri	Alfa Romeo	114.41	—
	,,	,.	A. Maserati	Maserati	—	124.4*
14/7/29	Marne G.P.	Rheims	P. Etancelin	Bugatti	85.5	88.6
14/7/29	German G.P.	Nürburg	L. Chiron	Bugatti	66.79	69.97*
21/7/29	Coppa Ciano	Montenero	A. Varzi	Alfa Romeo	54.17	—
,,	,, ,,	,,	T. Nuvolari	Alfa Romeo	—	55.3*
15/9/29	Monza G.P.	2.8 Mile Circuit of Monza	A. Varzi	Alfa Romeo	116.83	—
,,	,,	,,	A. Maserati	Maserati	—	124.21

Racing Statistics 1928-30 *(continued)*.

6/4/30	Monaco G.P.	Monaco	R. Dreyfus	Bugatti	54.63	56.01*
20/4/30	Bordino Prize	Alessandria	A. Varzi	Alfa Romeo	67.7	70.7*
4/5/30	Targa Florio	Short Madonie	A. Varzi	Alfa Romeo	48.48	49.1*
25/5/30	Rome G.P.	Trefontana	L. Arcangeli	Maserati	83.6	—
,,	,, ,,	,,	G. Bouriat	Bugatti	—	86.6*
29/6/30	Marne G.P.	Rheims	R. Dreyfus	Bugatti	88.5	91
20/7/30	European G.P.	Spa	L. Chiron	Bugatti	72.1	—
3/8/30	Coppa Ciano	Montenero	L. Fagioli	Maserati	54.47	—
3/8/30	,,	,,	T. Nuvolari	Alfa Romeo	—	57.2*
17/8/30	Coppa Acerbo	Pescara	A. Varzi	Maserati	75.35	—
17/8/30	,,	,,	L. Fagioli	Maserati		78.3*
7/9/30	Monza G.P.	4.3 Mile Lap Monza	A. Varzi	Maserati	93.55	100.6
21/9/30	French G.P.	Pau	P. Etancelin	Bugatti	90.4	—
4/10/30	Spanish G.P.	San Sebastian	A. Varzi	Maserati	86.82	91.09*

IN 1928 Grand Prix racing fell to a level only previously plumbed between 1908 and 1912. Fiat, Talbot and Delage withdrew factory support, leaving only Bugatti as a regular entrant of a works team, with Alfa Romeo making occasional appearance, and further entries from Maserati, a new Italian constructor. Furthermore, dissatisfaction with the formula proposed by the A.I.A.C.R. was so general amongst constructors, private entrants and organising clubs, that *formule libre* reigned except in the European Grand Prix at Monza on September 9th, run over sixty laps of the 10 kilometre course.

The entries were eleven Bugattis, four 1.7-litre supercharged Maseratis, three eight-cylinder Talbots, two four-cylinder Talbots and a single entry of Delage and Alfa Romeo. Of these only the Maserati cars were of a 1928 design ; the Bugattis were all Type 35 B or C ; the Delage was one of the 1925 twelve-cylinders ; the Alfa Romeo a 1925 P.2 model ; and the three straight-eight Talbots were the works' cars of 1927 now privately sponsored and with cylinders bored out to give a capacity of 1,750 c.c. The four-cylinder Talbots were even older designs which had run in the Voiturette races of 1924 and 1925.

The race soon showed that there was little difference in speed between the eight-cylinder Talbot and Bugatti models, Williams led on one of the Bugattis at the fifth, and Brilli-Peri was first on a Talbot at ten laps. Later Arcangeli on a Talbot lapped at 103.2 m.p.h. compared to the best by Williams of 102.8 m.p.h., both being slower than the 104.24 m.p.h. of the Alfa Romeo in 1924. Varzi did not push the only Alfa Romeo in the first half but came to the front on the fifteenth lap after a disaster in which Materassi's Talbot ran into the crowd, killing twenty-two and injuring twenty, after which the whole of this team was withdrawn. Varzi then handed the wheel to his

co-driver Campari, and Chiron on a Bugatti went into the lead which he maintained to win at 99.14 m.p.h., the Alfa Romeo being second at 98.37 m.p.h. The winning speed was a record for a complete race, the previous highest standing to the credit of Ascari, who in 1924 drove a P.2 Alfa at 98.76 m.p.h. for eighty laps.

A number of non-formula races were also held in 1928, chief amongst them were the Targa Florio and the German Grand Prix. There were also San Sebastian, the Grand Prix de la Marne, and the Circuits of Cremona and Montenero, this last used for the Coppa Ciano until 1934.

Of these, the Targa Florio was easily the most important, and deserves extended mention. As early as 1906 Count Florio put up a cup for a race held on an extremely arduous circuit in Sicily, the first winner being Cagno on an Itala at an average speed of 29.18 m.p.h. Reference has been made earlier to the post-war revival of this event in 1919 when it was won by A. Boillot on the Peugeot at 34.19 m.p.h. and it is interesting that not until 1924 did the average speed exceed 40 m.p.h., the winner in this year being Werner, whose 2-litre, four-cylinder supercharged Mercedes averaged 41.02 m.p.h. Starting in 1925 Bugatti secured three successive victories with his Type 35 cars and during these years, when public and manufacturers' interest in Formula Grand Prix racing sharply declined, increasing attention was given throughout the world to the Targa Florio event which retained the atmosphere of the true road races run over long circuits and normal roads 20 years previously. It is not unfair to claim that between 1928 and 1932 the Targa Florio usurped the French Grand Prix as the classic event of the year, although, by its very nature, the number who could witness it at first hand was small.

Alfa Romeo ran a works' team of three cars for the Targa Florio, these being the catalogue 1,750 c.c. blown six-cylinder model used in the various sports car races which were popular at this period. Five straight-eight Maseratis, three of 2-litre and two of l½-litre capacity, were entered, but the strongest numerical support was from Bugatti. Six Type 35 cars of 2-litre capacity, three of 2.3-litres and two Type 39 1.5-litres, supplemented by eight l½-litres of unspecified type entered by private owners, made up a total of nineteen entrants for this make alone.

The lead changed on each of the first three laps, passing from Chiron (2-litre Bugatti) to Mme. Junek (2.3-litre Bugatti) on the second lap, and then to Campari on the small Alfa Romeo on the third lap, in which Mme. Junek dropped to second.. In the fifth and last circuit the Alfa Romeo experienced tyre trouble, Mme. Junek dropped back to fifth and Divo on a 2.3-litre Bugatti finished first at 45.65 m.p.h., the Alfa running second at 45.43 m.p.h.

The German Grand Prix was held on the recently opened Nürburg Ring and run over twenty-two laps comprising 316.5 miles. Three supercharged 7-litre Mercedes proved overwhelmingly (and surprisingly) superior to the 2.3-litre Bugattis and finished first, second and third. Caracciola won at 64.6 m.p.h., whereas the best Bugatti (driven by Brilli-Peri, who finished fourth) could only manage 62.2 m.p.h. The Mercedes were almost identical with stock catalogue models and ran with headlamps and mudguards as did the thinly-disguised Type 35 Bugattis, for it should be noted that this was nominally a sports-car race.

Bugatti had, however, won two of the three big races for 1928 and secured many other victories in minor events. Chiron driving a works' car won the Grand Prix

de la Marne over the Rheims circuit at 82.5 m.p.h. (and made a record lap of 91.4 m.p.h.), the Rome Grand Prix at 78.55 m.p.h., and the San Sebastian Grand Prix at 80.58 m.p.h. with a record lap of 88.25 m.p.h. Nuvolari, a new Bugatti driver, scored at Alessandria at 63.45 m.p.h. and was second in the circuit of Montenero, which was won by a 1927 Talbot driven by Materassi at an average of 52.77 m.p.h.

On the Cremona circuit race Arcangeli drove a Talbot to win at 101.31 m.p.h., with Nuvolari on a Bugatti again second. The speed was 3 m.p.h. higher than that achieved four years previously by the 2-litre P.2 Alfa Romeo and a sister Talbot was timed over 10 km. at 129 m.p.h.

Talbot also secured fourth position at Alessandria at 59.88 m.p.h., and third in the Rome Grand Prix at 74.84 m.p.h., and were thus far more successful under private ownership than they had been as a works' team in the Grand Prix races of the previous two years.

The fate of the French Grand Prix in 1928 merits extended comment.

Before 1914 the "Grand Prix" was synonymous with the event organised by the Automobile Club de France. With the revival of European road racing in 1921 other countries-Italy, Spain and Belgium, for example-staged international road races, but although these were also termed " Grands Prix," the French event continued supreme in both public prestige and in the number of entries received from manufacturers. There were, for example, eighteen entries in 1921, twenty-two in 1922, eighteen in 1923, twenty-two in 1924, and seventeen in 1925. As already recorded, 1926, with only three starters, was a catastrophe and one from which this historic event never fully recovered. In 1927 there were eighteen entries but only seven starters and in 1928 the organisers waived Grand Prix status and ran a sports car event in conjunction with a handicap race. From this year onwards, therefore, we can no longer use the French Grand Prix alone as a touchstone of racing car success, but have to consider the overall results of many events in the season's racing.

For 1929 the A.I.A.C.R. produced a formula that was even more unpalatable than the one devised for 1928, so that the French and Spanish Grands Prix were the only " approved " international events.

The first named was run at Le Mans and was dominated by eight Type 35 Bugattis, Williams winning at 82.66 m.p.h. In the Spanish race a single Alfa was the only exception to thirteen Type 35 Bugattis, Chiron scoring his second successive win thereon at the modest average of 72.4 m.p.h., 8 m.p.h. slower than his speed of the previous year. This left four large races all of which were run under *formule libre.*

The 1929 Monaco Grand Prix was the first to be held, over a very twisty town circuit, which was later to be the scene of historic struggles, and Bugatti added to his series of victories with the Type 35 cars ; Williams being the winner at 50.23 m.p.h. Alfa Romeo were represented by two six-cylinder sports cars which failed to make any impression, the only rival to Bugatti being Caracciola on a shortened sports type Mercedes-Benz (Type SSK) who was at one time in the lead but was held back by stops for fuel and tyres, and finished 2 mins. 22 secs. behind.

In May the Targa Florio race was run over the usual circuit and was once more a Bugatti versus Alfa affair. Three Italian team cars competed against four works entered Bugattis, supplemented by four private owners ; two Maseratis were entered

but were not serious competitors as Bugatti kept a firm grip on first and second places throughout, Divo winning at 46.21 m.p.h., with a sports 1.750 c.c. Alfa a bad third.

The German Grand Prix was run during July and on this occasion Bugatti reversed the verdict of the previous year, Chiron winning at 66.79 m.p.h., another Bugatti second and a privately entered Mercedes third.

From every point of view the most important race of the year was the Monza Grand Prix. This was run as a substitute for the European Grand Prix which had been offered to the Italian club under the official regulations. There were three heats of 62 miles each (over a new short circuit of 2.82 miles per lap) for cars of l½-litre, 2-litre and unlimited capacity. The only entries in the unlimited class were two privately sponsored sports type Mercedes and a sixteen-cylinder 4-litre Maserati driven by Alfieri Maserati. In an exceedingly close race Momberger on a Mercedes averaged 107.74 m.p.h., beating the Maserati by one-fifth of a second. In the l½-litre class Arcangeli driving a 1927 type Talbot averaged 111.37 m.p.h., beating Nuvolari on a similar car by two seconds, and in the 2-litre heat Brilli-Peri averaged 114.85 m.p.h., on a P.2 Alfa, a Maserati being second and Varzi on another P.2 third.

The final was a triumph for the old capacity limit cars. Varzi was first on the 1924 P.2, averaging 116.83 m.p.h. Nuvolari was second with a 1927 Talbot at 111.03 m.p.h. and the big Mercedes came in third at 107.68 m.p.h.

The inherently sound design of the pure racing type P.2 Alfa Romeo was demonstrated by many other victories in Italian races. Varzi won the 2-litre class of the Rome Grand Prix at 70.2 m.p.h. (beating Divo on a Bugatti by 10 mins. in a three-hour race), the Bordino Grand Prix at Alessandria at 68.24 m.p.h., and the Coppa Ciano on the Montenero circuit at 54.17 m.p.h. On the Cremona circuit he was second to his team mate Brilli-Peri who averaged 114.4 m.p.h. and was timed at 138.77 m.p.h. over the same stretch of 10 kilometres down which Ascari averaged 123 m.p.h. on the first appearance of the car in 1924.

Concluding the story of the minor races, Bugatti won the Marne Grand Prix on the Rheims Circuit, Etancelin being first at 85.5 m.p.h., with a fastest lap at 88.6 m.p.h.

It will be observed that although Bugatti had won three out of the four big races, the older roller bearing, welded steel-cylindered cars of Talbot and Alfa continued to have a highly successful season, despite the one being three years old, and the other six years. Additionally, a relatively new make, Maserati, had, by its performance at Monza, come into the front rank of racing cars.

The A.I.A.C.R., with almost admirable obstinacy, continued with their complicated and completely unacceptable formula for 1930, allowing, however, a slight modification in that up to 30 per cent benzol could be mixed with pump fuel. These regulations were accepted only by the Belgian and French clubs and as it turned out the former was the only true formula race of the year. Run on the Spa Circuit, which had been used for the Grand Prix of 1925 (and for sports car racing in subsequent years), three Type 35 Bugattis were the only serious racing cars entered and Bouriat obligingly loitered at the end to let Chiron win at 72.1 m.p.h.

The Grand Prix de L'A.C.F. was run at Pau, and following an announcement that it would be run under *formule libre* instead of official regulations there were thirty-seven entrants and twenty-five starters, although neither Italian nor German concerns were present due to the short notice of this change of plan. Fourteen of the starters

were Type 35 Bugattis, and for the first time in five years an English car, a supercharged 4½-litre Bentley with four-seater Le Mans type body, entered by Sir Henry Birkin, Bt., was on the starting line. Driving the race of his life, Birkin gave additional proof that at this period a sports car could successfully compete with the pure racing type, for after lying fifth on the fifth lap he climbed to fourth on the tenth and third place on the fifteenth, thence forward retaining second position to average 88.6 m.p.h. for the race. A Type 35C Bugatti, driven by Etancelin, won at 90.4 m.p.h.

Three other events in 1930 may be reasonably entitled major races, the Targa Florio, Monaco Grand Prix and Monza Grand Prix. Since 1925 the Type 35 Bugatti had established a monopoly of success on the Sicilian Circuit with five successive wins and a record average speed of 46.21 m.p.h. The only rivalry had come from Alfa Romeo running sports models of lesser capacity and far lower h.p. In view of the 1929 victories of the P.2 model the works decided to rebuild two of these cars with a larger radiator and other modifications for use as an instrument of victory in the Targa Florio of 1930. However, in " training," chassis and suspension deficiencies presented so alarming a picture that they had no option but to withdraw and revert to the sports type, a decision challenged by Varzi, who was engaged as a works' driver. Reluctantly, he was given permission to start on one of the older models and with it broke the circuit record on his first lap and, never headed thereafter, won at the record average speed of 48.48 m.p.h., a staggering feat of endurance and virtuosity.

The 2.3-litre Type 35 Bugattis had a poor day, and but for trouble experienced by the " little " Alfas might not have finished in the first three. As it was they secured second and third positions.

In the second Monaco Grand Prix Bugatti secured his second successive victory, a private owner, Dreyfus, winning with a Type 35C at 64.63 m.p.h., an advance of nearly 5 m.p.h. on the previous year's speed.

Both these races were on slow circuits in the early part of the season. Held as usual at the end of the year the Monza races were run at extremely high speeds. A new circuit measuring 4.27 miles to the lap was chosen and five preliminary events led to a final over thirty-five laps, equalling 150 miles. The heats were run over 60 miles and Bugatti were first, second, and Maserati third, in the 2-litre class, Etancelin winning at 91.15 m.p.h. In the 3-litre category the new 2.5-litre Maseratis were first and third, Arcangeli winning at 98.4 m.p.h., with a slightly oversize P.2 Alfa Romeo second.

A 4-litre sixteen-cylinder Maserati, driven by the designer, won the unlimited class at 91.4 m.p.h. with a 7.2-litre Mercedes second, and an extra heat brought two further Alfa Romeo P.2's into a final, which was to prove an overwhelming triumph for Maserati.

In the earlier part of the race Nuvolari led on an Alfa P.2, but all three cars of this type suffered tyre trouble and were withdrawn. Towards the end Varzi's 2.5-litre Maserati, which had stopped for plugs, was lying sixth ; the lead held by Arcangeli on the other 2.5-litre car with A. Maserati lying second on his sixteen-cylinder model. By magnificent driving Varzi passed the larger (but older) car on the thirty-second lap and on the thirty-fifth got past Arcangeli to win by one-fifth of a second at 93.55 m.p.h.

As the Maserati was the first successful new design introduced into racing since 1927 it is appropriate to make brief reference to the specification.

The straight-eight engine had dimensions 65 x 94 mm., the cylinder block being formed from a single iron casting with a detachable head, carrying two valves per cylinder inclined at 90 degrees. The crankshaft ran on five bearings, only one of which was of roller type, and the tubular connecting rods also had white metal big ends. A Roots blower driven off the nose of the crankshaft gave a boost pressure of 9 lb., and with a 7:l compression ratio 175 b.h.p. was claimed for the engine at 6,000 r.p.m. The four-speed gearbox transmitted power to a torque tube drive and it is interesting to note that the gearbox casing, the torque tube, the centre part of the rear axle, brake shoes and brake drums were all made from magnesium alloy.

Monza was by no means the only scene of success of this design. As early as May, Arcangeli won the Rome Grand Prix at 83.6 m.p.h., although (after the withdrawal of Varzi and Nuvolari on the P.2’s) Chiron on a Type 35B led until the last yard and put in the best lap at 87.23 m.p.h. Fagioli with a Maserati won the Coppa Ciano at 54.47 m.p.h., and Varzi was first on the same make at San Sebastian, averaging 86.82 m.p.h. and raising the lap record to 91.09 m.p.h., and also at Pescara where Fagioli’s Maserati made fastest lap.

Apart from the Targa Florio Alfa wins were confined to the Alessandria Circuit, on which Varzi beat a Bugatti, averaging 67.7 m.p.h.

Bugatti won three major races, also the Marne Grand Prix, in which Dreyfus raised the race record for the Rheims Circuit by finishing first at an average of 88.5 m.p.h., but generally experienced a disappointing year, in which Maserati was clearly the most successful design.

The other constructors now faced problems. Bugatti realised that his Type 35 with an engine design dating back basically to 1922 was under-powered, and Alfa Romeo found that the seven year old P.2 model was suffering from wear and tear, and that springs, brakes and chassis, designed for 120 m.p.h., were inadequate at speeds of 140 m.p.h. Thus, despite the world financial crisis the logic of events forced constructors to produce new racing designs for the 1931 season. In so doing they were much influenced by the growing political importance of racing, Mussolini in particular giving every encouragement to Italian constructors, who were told that motor racing victories were a big contribution to the home and world prestige of Fascist Rule.

CHAPTER TEN

The Turn of the Tide

RACING STATISTICS 1931-33

Date	*Event*	*Course*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Lap Speed (Rc'd*)*
19/4/31	Monaco G.P.	Monaco	L. Chiron	Bugatti	54.09	56.01
10/5/31	Targa Florio	Long Madonie	T. Nuvolari	Alfa Romeo	40.39	—
10/5/31	Targa Florio	Long Madonie	A. Varzi	Bugatti	—	43.8*
24/5/31	Italian G.P.	Monza	G. Campari & T. Nuvolari	Alfa Romeo	96.17	105*
2/6/31	Eifel Races	Nürburg Ring	R. Caracciola	Mercedes	67.67	—
21/6/31	French G.P.	Montlhéry	L. Chiron & A. Varzi	Bugatti	78.21	—
21/6/31	,,	,,	L. Fagioli	Maserati	—	85.6*
5/7/31	Marne G.P.	Rheims	P. Lehoux	Bugatti	89.49	92.78 *
12/7/31	Belgian G.P.	Spa	W. Williams & Count Conelli	Bugatti	82.04	—
12/7/31	,,	,,	L. Chiron	Bugatti	—	88*
19/7/31	German G.P.	Nürburg Ring	R. Caracciola	Mercedes	67.4	—
19/7/31	,,	,,	A. Varzi	Bugatti	—	72.6*
16/8/31	Coppa Acerbo	Pescara	G. Campari	Alfa Romeo	81.68	—
16/8/31	,,	,,	T. Nuvolari	Alfa Romeo	—	83.4*
6/9/31	Monza G.P.	4.3 Mile Lap Monza	L. Fagioli	Maserati	96.6	—
6/9/31	,,	,,	T. Nuvolari	Alfa Romeo	—	101.23*
27/9/31	Czechoslovak G.P.	Brno	L. Chiron	Bugatti	73.26	75.36*
17/4/32	Monaco G.P.	Monaco	T. Nuvolari	Alfa Romeo	55.81	—
17/4/32	,,		A. Varzi	Bugatti	—	58.3*
8/5/32	Targa Florio	New Short Madonie	T. Nuvolari	Alfa Romeo	49.27	50.7*
29/5/32	Eifel Races	Nürburg Ring	R. Caracciola	Alfa Romeo	70.7	72.8*
5/6/32	Italian G.P.	Monza	T. Nuvolari	Alfa Romeo	104.13	—
5/6/32	Italian G.P.	Monza	L. Fagioli	Maserati	—	112.22*

Racing Statistics 1931-33 (continued).

3/7/32	French G.P.	Rheims	T. Nuvolari	Alfa Romeo	92.26	99.5*
17/7/32	German G.P.	Nürburg Ring	R. Caracciola	Alfa Romeo	74.13	—
17/7/32	,,	,,	T. Nuvolari	Alfa Romeo	—	77.55*
31/7/32	Coppa Ciano	Montenero	T. Nuvolari	Alfa Romeo	53.91	54.5
14/8/32	Coppa Acerbo	Pescara	T. Nuvolari	Alfa Romeo	86.89	—
14/8/32	,,	„	T. Nuvolari	Alfa Romeo	—	90.3*
4/9/32	Czechoslovak G.P.	Brno	L. Chiron	Bugatti	67.67	73.73
11/9/32	Monza G.P.	Monza	R. Caracciola	Alfa Romeo	110.8	—
11/9/32	„	„	T. Nuvolari	Alfa Romeo	—	113.7*
3/4/33	Monaco G.P.	Monaco	A. Varzi	Bugatti	57.04	59.77*
28/5/33	Targa Florio	New Short Madonie	A. Brivio	Alfa Romeo	47.56	—
,,	„ „	„	I. Borzachini	Alfa Romeo	—	49.6*
11/6/33	French G.P.	Montlhéry	G. Campari	Maserati	81.52	86.6*
2/7/33	Marne G.P.	Rheims	P. Etancelin	Alfa Romeo	90.59	—
2/7/33	,,	„	G. Campari	Maserati	—	96
9/7/33	Belgian G.P.	Spa	T. Nuvolari	Maserati	89.23	92.33*
30/7/33	Coppa Ciano	Montenero	T. Nuvolari	Maserati	54.18	55.38
13/8/33	Coppa Acerbo	Pescara	L. Fagioli	Alfa Romeo	88.03	—
13/8/33	,,	„	T. Nuvolari	Maserati	—	90.4*
10/9/33	Italian G.P.	Full Monza	L. Fagioli	Alfa Romeo	108.58	115.82*
10/9/33	Monza G.P.	2.8 Miles Lap Monza	M. Lehoux	Bugatti	108.99	—
10/9/33	„	„	Count Czaykowski	Bugatti	—	116.81
17/9/33	Czechoslovak G.P.	Brno	L. Chiron	Alfa Romeo	63.57	70.8
24/9/33	Spanish G.P.	San Sebastian	L. Chiron	Alfa Romeo	83.32	—
2419133	„	,,	T. Nuvolari	Maserati	—	96.59*

BY 1931 the A.I.A.C.R. had failed for three successive years to produce a formula agreeable to either constructors or race organisers. The complex regulations intended to cover the 1931-33 seasons were equally unacceptable and were withdrawn *in toto* leaving a *formule libre* subject to there being no mechanic carried on the car and races lasting ten hours. This time limit involved an immense increase in the distances over which races were run, and led to the use for the first time, in international Grand Prix racing, of two drivers per car,

The Targa Florio was the first race of 1931 and stood as usual outside the formula. This notwithstanding, competition was between the two leading makes of Grand Prix car, to wit, Bugatti and Alfa Romeo.

The French constructor now had a re-engined version of the historic Type 35 car, designated the Type 51, in which the principal change was a double overhead camshaft eight-cylinder engine having two valves per cylinder. This gave approximately 160 b.h.p. as compared to the 135 b.h.p. of the older model with twenty-four vertical valves.

Alfa Romeo started the season with an entirely new type which came to be called the " Monza." This was an eight-cylinder racing version of the six-cylinder 1¾-litre supercharged sports car which the Company had been running in suitable events for some time. The bore and stroke of 65 x 88 mm. were identical, and although the engine was a straight-eight like the P.2, it had, unlike that famous model, a cast-iron cylinder block and white metal bearings throughout. The principal novelty lay in the drive to the camshaft and supercharger which was through a train of gears between two separate blocks of cylinders with the crankshaft made in two parts bolted together through the primary gear wheel. A single Roots blower was mounted on the right-hand side of the crankcase. This engine gave 160 h.p. at 5,400 r.p.m., that is some 50 h.p. more than the 1,750 c.c. model and roughly 10 b.h.p. less than the P.2.

The chassis of completely conventional design was a marked improvement on the 1924 Grand Prix type.

The car put up an excellent show in its first race. A landslide necessitated the use of a lengthened circuit in Sicily, and although Varzi on the Bugatti showed himself to have the fastest car a combination of heavy rain-storms with front mudguards on the Alfa permitted Nuvolari to win at 40.3 m.p.h.

The first formula race was the Italian Grand Prix run at Monza on May 24th. Both Alfa Romeo and Bugatti entered full works' teams, to which were added a 2½-litre Maserati and two Talbots and one Delage dating from 1927. The Bugatti works' team all drove the Type 51 model, but the two Monza Alfas were joined by a remarkable twelve-cylinder Monoposto car, the predecessor of the later P.3 model which annexed this designation. The power plant consisted of two six-cylinder sports car engines each with its own clutch and gearbox, giving a total swept volume of 3½ litres and developing well over 200 b.h.p. at 5,000 r.p.m. A spherical universal joint was mounted behind each gearbox and the drive was taken to the rear axle by two propeller shafts, each enclosed in its own pressed-steel torque tube. The back axle contained two separate differential gears in aluminium castings and mounted side by side.

The driver sat in the centre of the car above the two propeller shafts and each gearbox retained a gear lever, these being coupled together so that left- or right-hand changes could be effected. This car had a wheelbase of 9 ft. 6 in. and a track of 4 ft. 9 in. and weighed some 23 cwt.

In the Italian Grand Prix this literal " twin six " was not successful, Nuvolari being third at the end of two hours and then retiring. At this point Varzi was first on a Bugatti and Campari second on a Monza Alfa, but by the end of the fourth hour Bugatti had in turn retired with back axle trouble, after which the Monzas were never displaced from first and second positions. Campari, aided by Nuvolari in the latter

part of the race, covered 961.7 miles in ten hours over the full Monza circuit and the 1924 lap record was broken by 0.76 m.p.h.

June saw a non-formula event over the Nürburg Ring which was the beginning of the Eifel series of races on the full length of this course. It was won by a sports type Mercedes-Benz against little opposition.

The French Grand Prix, held at Montlhéry on the 21st June, was a ten-hour formula event. Early on the lap record was raised to 85.6 m.p.h. by Fagioli, driving one of the 2½-litre straight-eight Maseratis which had been so successful in the previous year, but, once again, " the race was not to the swift," for after leading for the first two hours and running second in the third and fourth hours the car was held back with brake trouble. This gave victory to Chiron and Varzi driving a Bugatti Type 51, in which they covered 782.1 miles, second being a Monza Alfa driven by Campari and Borzacchini who covered 755 miles. It is worth noting that in this immensely long race the winning Bugatti had only five pit stops, aggregating 10 mins. 30 secs., whilst the Alfa stops totalled 24 min.

Bugatti was to have a string of successes in 1931 and the victory of the new twin camshaft model at Montlhéry was followed by a win in the lesser Marne Grand Prix run at Rheims. Lehoux beat Dreyfus on a Maserati and in doing so put up a record speed both for the lap and for the whole distance.

Bugatti scored a third success in the formula race run at Spa in mid-July, Alfas being second and third. The race was a very close one, the Englishman, Williams, and the Italian, Count Conelli, jointly covering 820.1 miles, whilst Nuvolari and Borzacchini covered 813.3 miles. The winners made only three stops, aggregating 5 min. 4 sec., and owing to the wheels and brake drums being one casting they were able within this time to change all the brake shoes. The runners-up made four stops lasting 8 min. 45 sec.

Within a week Bugatti and Alfa, together with a Maserati, were running on the Nürburg Ring in the German Grand Prix, and on this very difficult circuit it is of particular interest that Caracciola, driving a modified version of the 7-litre Mercedes-Benz car, was able to beat the smaller models, averaging 67.4 m.p.h. for twenty-two laps. This repeated the lesson of the Eifel races held earlier in the year, but there was stronger opposition in the German Grand Prix and Varzi on a Bugatti made the fastest lap. Neither this event nor the Monza Grand Prix run in September complied with the international formula. The latter was held on a fraction of the full course giving circuit of approximately 4.3 miles per lap and the preliminary heat for cars of up to three litres, run over fourteen laps, had entries from Alfa Romeo, Bugatti and Maserati. The last named had two cars with engines enlarged to 2.8-litres and these led alternately, Fagioli winning with Dreyfus second. The average of 97 m.p.h. was appreciably slower than the speed in the equivalent event of 1930.

The race for cars of unlimited capacity attracted two twelve-cylinder twin-engined Alfa Romeos, the sixteen-cylinder (twin eight) Maserati and Bugatti's newest car, the 86 x 107 mm. 4.9-litre Type 54 which was making its racing debut. Although holding the ten kilometre record at 152.9 m.p.h., the big Maserati was never in the picture at Monza, Varzi winning on a Bugatti at 98.5 m.p.h. and Nuvolari on one of the twelve-cylinder Alfas breaking the lap record for this short circuit at 101.25 m.p.h. The line-up for the final consisted of three Monzas and one twelve-cylinder Alfa, two Type 54 and one

Type 51 Bugatti, and two 2.8litre Maseratis. Fagioli on the Maserati showed himself clearly superior to the opposition, winning at 96.6 m.p.h. despite a tyre stop. Nuvolari was never better than third on the twelve-cylinder Alfa and Borzacchini ran second with the Monza model. Varzi on a Type 54 Bugatti challenged the winner in the early parts of the race but had two burst tyres.

The Type 51 Bugatti scored a victory in the final race of the year which was the second Czechoslovak Grand Prix run over a fast circuit at Brno. The previous year the race had been largely an amateur affair, but it was now supported by Bugatti, by the Austrian, Hans Stuck, and Caracciola (both driving Mercedes-Benz cars) and by works' cars from Alfa Romeo and Maserati. On an early lap Fagioli, driving a Maserati, brought down a bridge crossing the track which led to the withdrawal of his own car, two Alfa Romeos and Caracciola. Chiron then had an easy win from Stuck.

The year was noteworthy for the emergence of three entirely new designs, to wit, the Type 54 Bugatti, the Monza Alfa and the twelve-cylinder Monoposto from the same company. Both the 2.8litre Maserati and the Type 51 Bugatti showed useful improvement in performance over their immediate predecessors and the evidence shows that in 1931, as in 1930, the former was the fastest road racing car.

In 1932 Bugatti decided to continue with his two established designs rather than to tempt fortune in the production of an entirely new car. Maserati had good grounds for confidence and they also continued with their current models. Alfa Romeo took a different line. The Monza, although a reasonably successful type, had little, if any, margin of superiority over competing designs and was incapable of providing the manufacturers with the decisive successes which are sought by all racing engineers. The twelve-cylinder car was promising, but heavy and not too easy to handle. These facts led the company to introduce the celebrated eight-cylinder P.3 car, which may be best described as a blend of the Monza and twelve-cylinder themes.

The P.3 engine, as on the Monza, was an eight-cylinder and had the same bore, but the stroke was increased to 100 mm., giving a capacity of 2.65-litres. The inlet and exhaust sides of the engine were reversed and two superchargers, both connected to the central auxiliary drive, were mounted on the left-hand side of the crankcase. The details of the car are fully revealed on other pages of this book, but it is relevant to note here that although a single gearbox was employed the notion of twin propeller shafts with the driver mounted centrally above them was continued, although the differential mechanism was placed behind the gearbox, instead of in the rear axle housings as it had been on the twelve-cylinder type.

This design was not available for the first two road races of the year, that is the Monaco Grand Prix and Eifel Races, but both were won by the Monza type Alfa, the driver in the first being Nuvolari and in the German event Caracciola. In both races the Type 51 Bugatti put up a stern fight. At Monaco Chiron driving one of these cars was leading for much of the race, when a rare error of judgment caused the car to crash, whilst another Bugatti driven by Varzi made the best lap at 58.3 m.p.h. In the German race Dreyfus on a Type 51 was beaten by only 22 sec. in a race lasting nearly three hours.

Following these initial races the true Grand Prix season began, a notable feature being the widespread acceptance of an A.I.A.C.R. ruling giving *formule libre* except

that no mechanic could be carried, that the duration of the race should not be less than five and not more than ten hours, and that no more than four persons, including the driver and spare driver, could work on the car at the pits. The organisers of the Italian Grand Prix, run on the 5th June, decided to limit the race to five hours over the full Monza circuit. Six Alfa Romeo cars, four entered by the works, competed against five Bugattis, three entered by the works, and four Maseratis, two entered by the works. The sixteen-cylinder Maserati now showed what it could do by putting up a lap record of 112.22 m.p.h., an immense advance over anything hitherto recorded on this circuit, but, unfortunately, Fagioli's skill at the wheel was by no means equalled by the rapidity of the Maserati mechanics in the pits. They took no less than 3 mins. 7 secs. to change four tyres and refuel, and this reduced the Maserati to ninth place on the twenty-fifth lap. Although consistently the fastest car on the course it could do no better than finish second, covering 515.6 miles compared to the 520.5 miles achieved by Nuvolari, who won on the new P.3 Alfa. After a lapse of eight years design was really advancing, for the winning average of 104.13 m.p.h. for five hours nearly equalled the 1924 P.2 lap record of 104.24 m.p.h. and was less than 1 m.p.h. slower than the 1931 lap record of 105 m.p.h. put up by the Monza model. Neither the Type 54 nor Type 51 Bugattis could make any impression in this extremely fast race.

The next event was the French Grand Prix, held once more on the road over the Rheims Circuit, which had for some years been used for the Grand Prix de la Marne. Bugatti again entered both Type 54 and 51 cars, Alfa entered three P.3's, to which were added four Monzas. The result was a clear demonstration of P.3 supremacy, only Varzi on a Type 54 making a challenge in the first five laps. Thereafter the P.3's annexed the three leading positions, Nuvolari breaking the lap record for the course at 99.5 m.p.h. and winning at 92.26 m.p.h. At the end of five hours the second P.3 was 400 yds. behind the winner and the third less than one mile in arrear.

The German Grand Prix was even more remarkable, for Bugatti decided to send only one Type 51 and Maserati only one 2.8-litre car. At the end of seven laps the only cars running were the Alfa team of P.3's and a privately owned Bugatti, Caracciola driving for the Italian concern, averaged 74.13 m.p.h. for 354 miles.

The major racing of the year was concluded by the Monza Grand Prix, run as usual in heats and a final, but this year the full circuit was used and in preliminary heats Nuvolari did a lap on a P.3 at 113.7 m.p.h. In the final he was unable to equal this speed and, suffering from carburetter flooding, finished third. Caracciola upheld the honour of the team by finishing first at 110.8 m.p.h., 1 min. 9 sets. ahead of Fagioli on the 4-litre sixteen-cylinder Maserati, who averaged 108.2 m.p.h. after suffering plug trouble.

After the excellent season of 1931 Bugatti had the disappointment of not winning any major races in 1932. But in the Czechoslovak Grand Prix, run as usual on the Brno circuit, he had the distinction of being the only constructor to beat the P.3 Alfa Romeo in fair fight.

This race was run only a week before the Monza Grand Prix and the Alfa Romeo team consisted of only two cars driven by Nuvolari and Borzacchini. These two led the race in the initial stages but Nuvolari had to change a magneto and lost so much time that he finished third. Borzacchini had rear axle trouble and retired, giving Chiron an easy win on a works Type 51 Bugatti. As he also made the best lap he thoroughly deserved his success.

Two P.3's were first and second in the Coppa Ciano over the Montenero circuit, which Nuvolari won at 53.91 m.p.h., a similar statement being true for the Coppa Acerbo where his winning speed was 86.89 m.p.h. Apart from the Brno mishap the only occasion in 1932 when a P.3 was beaten was on the neglected Miramas track, which was used for the Marseille Grand Prix on the 25th September. The Alfa pit made a miscalculation in the lap score and the race was won by an independently entered Monza model.

The regulations effective for the 1933 racing season amended the duration of the racing to 500 kilometres, but a considerable change came over the racing situation following the decision of Alfa Romeo to retire from racing and to put the P.3 model into storage. An organisation headed by Ferrari commenced the season by running a team of Monza cars with engines bored out to 2.55-litres and carrying an offset single-seater body. Both Bugatti and Maserati abandoned their big cars, the former concentrating on the Type 51 and the latter developing a 2.9-litre 69 x 100 mm. straight-eight.

The German Grand Prix was cancelled owing to economic difficulties, so that the five major events of the year were the Grands Prix of Monaco, France, Belgium, Italy and Spain, the latter revived after a lapse. At Monaco, Varzi showed that the Type 51 could match the modified Monza. Driving the French car to its limit he had a tremendous duel with Nuvolari who, on the last lap, broke an oil pipe, his Monza catching fire and being pushed until 200 yds. short of the finishing line. Varzi's winning speed was 57.04 m.p.h., with Borzacchini on a Monza model second.

This race has a special historic significance for it was the first in Europe in which the positions on the starting grid were. determined by the times made in practice. This arrangement had been used at Indianapolis for very many years and it was Faroux who perceived that on the very twisting course at Monte Carlo a fast car which had the ill-luck to draw a back row position by ballot would be most unfairly handicapped, and who suggested the Indianapolis arrangement to the organisers. Starting positions in the 1933 Marne Grand Prix were similarly established but this method did not come into general use until 1935.

Bugatti had planned to run an entirely new 2.8-litre car in the French Grand Prix, held at Montlhéry on the 1lth June, but as they were not ready five privately owned Bugattis competed with twelve Monza Alfas and two 2.9-engined Maseratis. Campari driving one of the last named led for practically the entire race, putting the lap record to 86.6 m.p.h., and winning at an average of 81.52 m.p.h. The runner-up was a privately entered Monza, which averaged 81.21 m.p.h., a similar car entered and owned by G. E. T. Eyston finishing third. After the race Nuvolari had a dispute with Ferrari over the preparation of the Alfa cars for the French race and then drove a Maserati in the Belgian Grand Prix at Spa, which he won. Both the Monzas entered by Ferrari retired and Bugatti ran second and third. Varzi finished 3 mins. behind Nuvolari, who averaged 89.23 m.p.h. and broke the lap record at 92.33 m.p.h.

Alfa Romeo continued their successive victories in the Targa Florio by winning the 1933 race at 47.56 m.p.h., but, generally speaking, the events held up to the end of July had shown the modified Monza model inferior to the 2.9-litre Maserati. The latter car won not only the French and Belgian Grands Prix, but also the Coppa Ciano, where Nuvolari beat the Alfa Romeo driven by Brivio by the resounding margin of eight minutes. To offset these defeats the works decided to release the P.3 models to the Ferrari organisation and two of them accordingly re-appeared in, the Coppa Acerbo

run on the 13th August. In the early stages of the race they proved slower than the 2.9-litre Maserati of Nuvolari who led Campari's P.3, but the latter broke down and the former had to make a pit stop, and this gave the P.3 driven by Fagioli victory by virtue of making a non-stop run. This event could be considered a rehearsal for the major races for the Italian and Spanish Grands Prix, which in accordance with tradition were held late in the racing season. The Italian Grand Prix was run over fifty laps of the full course of Monza in the morning of September 10th, the afternoon of the same day being reserved for the heats and final of the Monza Grand Prix run on the short circuit used in 1929.

The Italian Grand Prix was notable for a tremendous struggle between Nuvolari, on a 2.9 Maserati, and Fagioli and Chiron both driving P.3 Alfa Romeos. Nuvolari led on the first, sixth, ninth, twelfth, fifteenth, twenty-seventh, forty-first and forty-eighth laps, Chiron on the eighteenth, thirtieth and thirty-fifth laps, Fagioli on the fifth, seventh and last lap. Fagioli's winning speed was 108.58 m.p.h., and he covered the forty-first lap at the record speed of 115.82 m.p.h., but Nuvolari was definitely deprived of victory by a burst tyre on his forty-eighth lap, despite which he finished second at the average of 108.19 m.p.h.

The Monza Grand Prix followed and is known to history on account of a burst tank on one of the competing cars, which led to oil being spread over one of the fast turns. Inefficient cleaning of the track at this point led to accidents, causing the death of Campari, Borzacchini and Count Czaykowski on a Type 54 Bugatti. Before he was killed Czaykowski lapped this short circuit at 116.81 m.p.h., Moll on a Monza Alfa having achieved 115.95 m.p.h. on a preceding lap.

Barely a week later the P.3 Alfa Romeo continued its almost unbroken run of successes by gaining first place in the Czechoslovak Grand Prix, the poor speeds realised being fully explained by the appalling weather conditions in which the race was run.

In the Spanish Grand Prix Bugatti contrived to get his new 2.8-litre cars on to the line, but these, the precursors of the famous 3.3-litre Type 59 model, which rendered an excellent account of themselves the following year, had a far from sensational first appearance. They finished fourth and sixth, Chiron winning on a P.3 Alfa at 83.32 m.p.h. He was fortunate to do so as Nuvolari kept the Maserati comfortably in the lead until three-quarters distance, putting in a record lap at 96.59 m.p.h. and then having the misfortune to leave the road and hit a tree.

Although unsuccessful in major racing, in which they were frequently beaten by Maserati, the Monza type Alfas run by Ferrari were very successful in minor events. The year was, however, chiefly remarkable for the continuing successes of Maserati cars which showed that they could compete on even terms even after the celebrated P.3 Monoposto Alfa Romeos had been released from retirement. Bugatti had a shocking racing season due largely to the difficulties experienced in bringing out his entirely new car.

Speeds over full distances and on the lap had in most cases increased and the faster cars were now capable of over 140 m.p.h. This trend caused some alarm in the international governing body, who hoped that the new formula governing the years 1934-37 would limit speeds and serve to break up the Italian monopoly of racing successes. It was, as we shall see, highly successful in this latter respect.

CHAPTER ELEVEN

The New Order

RACING RESULTS 1934

Date	Event	Course	Driver	Car	Average Speed m.p.h.	Lap Speed m.p.h.
2/4/34	Monaco G.P.	Monaco	G. Moll	Alfa Romeo	55.86	—
2/4/34	,,	,,	Count Trossi	Alfa Romeo	—	59.7*
3/6/34	Eifel Races	Nürburg Ring	M. von Brauchitsch	Mercedes-Benz	76.12	79*
17/6/34	Penya Rhin	Montjuich	A. Varzi	Alfa Romeo	64.24	—
17/6/34	,,	,,	L. Chiron	Alfa Romeo	—	66.25*
1/7/34	French G.P.	Montlhéry	L. Chiron	Alfa Romeo	85.55	91.44*
8/7/34	Marne G.P.	Rheims	L. Chiron	Alfa Romeo	90.71	—
8/7/34	,,	,,	A. Varzi	Alfa Romeo	—	97.65
15/7/34	German G.P.	Nürburg Ring	H. Stuck	Auto-Union	75.14	79.29*
29/7/34	Belgian G.P.	Spa	R. Dreyfus	Bugatti	86.9	—
29/7/34	,,	,,	Brivio	Bugatti	—	96.38*
15/8/34	Coppa Acerbo	Pescara	L. Fagioli	Mercedes-Benz	80.26	—
15/8/34	,,	,,	G. Mall	Alfa Romeo	—	90.5*
26/8/34	Swiss G.P.	Berne	H. Stuck	Auto-Union	87.21	—
26/8/34	Swiss G.P.	Berne	A. Momberger	Auto-Union	—	94.42*
9/9/34	Italian G.P.	2.68 Miles at Monza	R. Caracciola and L. Fagioli	Mercedes-Benz	65.37	—
9/9/34	,,	,,	H. Stuck	Auto-Union	—	72.59*
23/9/34	Spanish G.P.	San Sebastian	L. Fagioli	Mercedes-Benz	97.13	—
23/9/34	,,	,,	H. Stuck	Auto-Union	—	101.96*
30/9/34	Czcchoslovak G.P.	Brno	H. Stuck	Auto-Union	79.21	—
30/9/34	,,	,,	L. Fagioli	Mercedes-Benz	—	81.23*

* Record

SINCE October, 1932, racing car designers had known that in the years 1934, '35, '36, racing was to be governed by a formula wherein cars without driver, fuel, oil and tyres must weigh less than 750 Kg. (14.73 cwt.) and that the body width must be at least 33.5 in.

The winter of 1933 saw the principal adversaries of the past two years working in quiet confidence in their Italian establishments. Alfa Romeo were under contract

to deliver to the Ferrari group a set of cars complying with the new regulations, but they were only slightly modified versions of the P.3 model which had been beaten only twice in the past two years. Wheelbase and track were enlarged, bodies were widened to comply with the new regulations, and the weight rose to a little over 14 cwt. The engine capacity was raised to 2.9-litre capacity by opening up the cylinder bores from 65 mm. to 69 mm., the stroke remaining unchanged at 100 mm. These minor modifications took no great time and in January, 1934, a car was tested over the Montenero Circuit which had been the scene of the Coppa Ciano races.

Maserati continued with the 2.9-litre straight-eight car which had made its debut at Tunis in 1932 and with which they had four good wins in 1933, including the French and Belgian Grands Prix. In view of the new body regulations the width between chassis members was increased from 20 in. to 30 in., but, this apart, the car underwent little change.

Bugatti went on with the new 2.8-litre car which he had run at San Sebastian the previous September, a model, which, with its unique wire wheels, plain bearing engine, double reduction drive to the rear axle, and offset driving position, showed a marked change from previous Molsheim models.

Overshadowing all these activities of the established constructors were two new German cars. One of these marked the return of Mercedes-Benz to Grand Prix racing after an interval of ten years, the other the entrance upon the stage of the recently formed Auto-Union combine (Horch, Audi, Wanderer and D.K.W.), who had taken over a design by Dr. Porsche which had originally been a private venture.

The German Government, under Adolf Hitler, had offered a prize of £40,000 to the most successful German racing car of 1934 and Porsche’s design, which embraced tubular frame with independent springing to all four wheels and a 4.36-litre sixteen-cylinder rear-mounted engine, was an ambitious and highly original attempt to secure this reward. Although an entirely new concept construction was very well forward, and in December of 1933 one car had a preliminary trial on the Nürburg Ring followed by tests in January, 1934, on the Autostrada between Milan and Varese, speeds of 155 m.p.h. were mentioned, and any doubts concerning the immense potency of this design were set at rest when it broke the one-hour record on the A.V.U.S. Track on March 6th. The speed of 134.608 m.p.h. could be directly compared with the 4.9-litre Bugatti which had averaged 132.87 m.p.h. on the same track in the previous year.

The 1934 Mercedes-Benz had an orthodox 3.3-litre engine of eight cylinders conventionally positioned, but was also notable for using independent suspension to all four wheels. It also was taken during January to the Milan-Varese Autostrada, but it is evident that these tests showed the constructors that the cars were by no means ready for serious racing, for they made no effort to appear in the initial race under the new formula, which was run at Monte Carlo in May.

The Auto-Unions were also non-starters as they were thought unsuitable for this race owing to their long wheelbase, so the old guard, Bugatti, Maserati and Alfa Romeo, were thus left to fight their battles alone.

Bugatti and Alfa Romeo had no difficulty in meeting the weight limitation, but Maserati had to resort to fearful expedients, even draining the rear axle of oil.

In practice Count Trossi, on an Alfa Romeo, equalled the lap record set up on a Type 51 Bugatti the previous year, but the new Bugattis in the hands of Dreyfus, Wimille and Nuvolari proved to be much slower. In the race itself the Alfas remained steadily at the head of affairs, running, however, at a consistently lesser speed than Varzi's Bugatti in 1933, so that in the end Moll won at an average of only 55.86 m.p.h., Chiron following on another Alfa Romeo a minute later at 55.8 m.p.h., and Dreyfus brought home the fastest Bugatti in third place at 55.2 m.p.h.

It seems likely that the Alfa Romeo brakes were not quite adequate to this type of race, whilst the Bugattis had not at this stage such good acceleration as the previous models. One might have thought that these factors would have permitted Maserati to go into the head of affairs, but for some reason they failed to take advantage of the opportunity thus presented and at half distance were in no better than sixth, although they would have gained fourth place if their best car had not retired on the very last lap.

The German constructors chose a *formule libre* event run on the A.V.U.S. track near Berlin on May 27th as the scene of the first trial of strength between the new order of highly unconventional cars produced with lavish expenditure and State encouragement, and the established classic designs in which development had proceeded step by step over a number of years constrained by moderate expenditures of cash and man-hours. In practise for this event one of the Mercedes-Benz cars was timed at 143 m.p.h. for the lap, but the Stuttgart engineering department decided that the cars were not yet fit for a long distance event and they were all withdrawn.

The Auto-Union team remained to compete against the Ferrari-sponsored Alfa Romeos, one of which was given a fully faired body and an enlarged engine of 3.2-litre capacity. This car, driven by Guy Moll, eventually proved the winner at 127.56 m.p.h. after two of the Auto-Unions retired at fifth and twelfth laps respectively. The third, driven by a relatively inexperienced driver, finished in third position at 125 m.p.h.

Both of these events it should be noted were slower than the corresponding races of the previous year, and at this point, therefore, the authors of the new formula seemed to have justified their belief that it would curb average speeds. Such satisfaction was to be very short lived, for within a week the Eifel Races, held on the Nürburg Ring, were to demonstrate the potentialities of the new, and to sound the knell of the established, designs. A Mercedes-Benz, driven by von Brauchitsch, led throughout the race and raised the 1932 lap from 77.55 m.p.h. (R. Caracciola on a P.3 Alfa Romeo) to 79 m.p.h.

At half distance Brauchitsch was followed by his team mate, Fagioli, with Stuck on the Auto-Union third, with Chiron leading the van for Italy but completely outclassed.

Fagioli was later engaged in a remarkable dispute with team orders, for although he could clearly take the lead whenever he wished, he was ordered to remain in second position, to which he responded by stopping his car and walking away. This let the Auto-Union into second position and Chiron's Alfa Romeo into third. The Alfa, however, finished 5 min. 44 sec. behind the Mercedes-Benz and 4 min. 24 sec. behind the Auto-Union. From the technical viewpoint the German win was the more creditable as both the leading cars had to refuel, whereas the Alfa Romeo team were able to run the distance non-stop.

The Penya Rhin Grand Prix was run for the second time on the Montjuich

circuit at Barcelona, and the official Alfa team had no significant opposition and filled the first three places.

The stage was now set for an historic struggle for the Grand Prix of the Automobile Club de France in a race to be run at Montlhéry on July 1st. The reliability of the German cars having been apparently established at Nürburg Ring it was generally considered that they would have little difficulty in beating their French and Italian rivals, consisting of three Bugattis with engines now enlarged to 3.3-litres capacity, three Alfa Romeos and three Maseratis, one of which was a non-starter.

In practice the lap record of 86.6 m.p.h., established by Campari on a Maserati the previous year, was beaten, not only by Brauchitsch on a Mercedes-Benz, but also by Chiron on the B Type Alfa Romeo, and it is not uninteresting that the latter were much the lightest cars, weighing in at 14.15 cwt. with both Maserati and Bugatti perilously near the maximum weight limit.

The starting line positions were determined by the ballot, but Chiron made a trick start and led on the first lap followed by Caracciola, Mercedes-Benz ; Fagioli, Mercedes-Benz ; Stuck, Auto-Union ; and Varzi, Alfa Romeo. Bugatti were right out of the picture, running eighth, ninth and twelfth, as were Maserati, who occupied tenth and eleventh positions. The first lap was symbolic of the entire race for it was only between the third and ninth (out of forty laps) that Chiron was overtaken. For this brief period Stuck led on the Auto-Union, but was delayed at a pit stop which brought him down to seventh position on the twelfth lap, finally retiring on the thirty-third lap when running fourth. Of his team mates, Prince Leiningen was a non-starter, and the relatively unskilled Momberger trailed along between tenth and thirteenth positions until he retired at quarter distance with suspension trouble.

Mercedes-Benz, also, were. in bad shape, for Caracciola went out with a cracked gearcase when running third at fifteen laps, Brauchitsch never really got his car going properly and retired on the twelfth lap, leaving Fagioli, the third member of the team, the only one to put up any fight. In the first part of the race he, Stuck and Chiron broke and re-broke the Maserati (Campari) lap record of 5 min. 23 sec. On the second and third laps it was lowered by Stuck to 5 min. 13.2 sec., and 5 min. 9.4 sec., and then by Fagioli on the ninth lap to 5 min. 8.8 sec., tenth lap 5 min. 8.6 sec., eleventh lap 5 min. 6.5 sec., twelfth lap 5 min. 6.4 sec.

For sheer speed Alfa, however, had the last word, for on the fifteenth lap Chiron put in a time of 5 min. .06 sec., or 91.4 m.p.h., which remained unbeaten. At 200 kilometres, on the sixteenth lap, this driver was leading his team mate Varzi by 1 min. 18 sec., and the nearest German car was Stuck, 5 min. 22 sec. behind the best Alfa. All the Mercedes-Benz had retired.

The poor position of Stuck in the face of his lap records was accounted for by numerous and lengthy pit stops. On the eleventh lap he took 2 min. 35 sec. to change the rear wheels and take on fuel and water, his subsequent pit calls being on the twentieth lap, 1 min. 22 sec. for fuel and water alone, and, finally, on the thirty-first lap, 1 min. 11 sec., again for fuel and water. The car was boiling on all of these stops. Caracciola had the rear wheels changed and his Mercedes-Benz refuelled in 1 min. 20 sec. on the fifteenth lap, whilst the best Alfa time was Varzi's on the eighteenth lap in which four wheels were changed and the car refuelled in 1 min. 30 sec.

From half distance onwards Chiron, Varzi and Moll took Alfa Romeo steadily forward to a 1, 2, 3 victory, and when the third car (which had suffered throughout the race from the absence of bottom and third gears) received the checkered flag, Benoist on one of the Bugattis was flagged off with three laps still to go. Thus, exactly twenty years after the dramatic Mercedes victory at Lyons the German cars were decisively beaten in the most famous of all Grand Prix races. The newer designs had been unable, either in reliability or sheer lap speed, to hold their own with the well-tried types.

This race was the zenith of Alfa Romeo fortune ; thereafter they were to secure occasional victories, but never by virtue of superior performance. They were to suffer many defeats at the hands not only of the German cars, but also of Bugatti.

The German Grand Prix, in which Alfa Romeo and Maserati had works' teams competing with Auto-Union and Mercedes-Benz, was an example of future events.

Nuvolari drove for Maserati, and although in the previous race held in 1932 he had gained second place and put up the record lap on a P.3 Alfa Romeo, this year he could do no better than finish fourth at an average of 72.04 m.p.h. His team mates made no serious contribution to the race and Alfa Romeo did little better, only Chiron lasting more than a quarter of the distance, to finish third at 74.21 m.p.h. with a best lap at 77.8 m.p.h., figures only fractionally better than those put up by the P.2 model two years previously. Stuck on an Auto-Union led almost throughout to win at 76.39 m.p.h., putting in a record for the ninth lap at 79.29 m.p.h., Caracciola lapped at 79.23 m.p.h., and came into the lead for the nineteenth lap, only to retire immediately afterwards, and another Mercedes-Benz, driven by Fagioli, finished second, 2 min. 7 sec. behind the Auto-Union, but 6 min. 6 sec. ahead of the best Alfa Romeo.

This was the second victory in succession for German cars on German soil, but they had yet to secure their first away victory, which made their entry for the Belgian Grand Prix all the more interesting.

Unfortunately, both Auto-Union and Mercedes-Benz decided not to start following a demand for heavy customs duty on the special fuel which they wished to bring with the team. Bugatti, however, returned to the field with three cars to compete against two Alfa Romeos. The French cars made a disastrous start, Brivio stopping three times in the first three laps, and losing 5 min. 23 sec., Dreyfus three times in the first three laps, losing 5 min. 22 sec., and Benoist one stop on the second lap which cost him 1 min. 5 sec. It is, therefore, scarcely surprising that at half distance the two Alfa Romeos were more than a lap ahead, shortly after which, however, Chiron got off the road and overturned his car. Varzi was left in an unchallengeable position, but on the twenty-second lap he decided to raise the lap record (standing to the credit of Nuvolari on the Maserati), which he did by the very considerable margin of nearly 4 m.p.h. This proved his undoing as the car then broke a piston letting two Bugattis into first and second places with an even faster lap thrown in for good measure. The Bugattis, however, thoroughly deserved their victory, for apart from the unfortunate stops in the first part of the race they generally proved themselves the faster cars.

All the leading makes were represented at Pescara for the Coppa Acerbo, and the comparatively even running of the cars was shown by the fact that there were five different makes in the five final positions. Unfortunately, the Auto-Union of Stuck

had mechanical trouble, Chiron's Alfa Romeo caught fire, Caracciola crashed the fastest Mercedes-Benz, and tragedy overtook Moll, who was killed when his Alfa Romeo crashed after being in the lead at half distance.

After this unhappy affair Fagioli's Mercedes-Benz kept comfortably ahead of Nuvolari's Maserati, with a Bugatti, driven by Brivio, running third.

The first Swiss Grand Prix was run over the Berne circuit and it proved a very fast course, over which an Auto-Union, driven by Stuck, led virtually from start to finish, averaging 87.21 m.p.h. For more than four-fifths of the distance Dreyfus on a Bugatti ran second, but was displaced by Momberger's Auto-Union (which raised the lap record to 94.42 m.p.h.) as a result of having to take on water. Alfa Romeo could do no better than finish fourth and fifth, and Mercedes-Benz suffered from various mechanical disabilities and did even worse.

The Stuttgart team, however, returned to the winning habit in the Italian Grand Prix run over a section of the Monza course with many *chicanes* put in to reduce average speeds. Stuck made the fastest lap at 72.59 m.p.h. and led at half distance. After this he ran into brake trouble and was passed by a Mercedes-Benz, the finish being in this order, with an Alfa Romeo third. Bugatti entered only one car which did not start.

This was a desperately slow race on a highly artificial circuit and contrasted unfavourably with the very high speeds realised in the Spanish Grand Prix run over the roads in the environ of San Sebastian. Nuvolari held the lap record at 95.69 m.p.h. on a Maserati, and at the end of the practice period both he and Dreyfus on 3.3-litre Bugattis had raised this speed to 99.5 m.p.h. During the race the Bugattis pressed hard on the heels of the two Mercedes-Benz, which held the first and second positions, Caracciola keeping the lead and putting the lap record at over three figures. He lost time in refuelling (which took 62 sec. with no wheel changing) and at half distance was 18 sec. behind his team mate Fagioli, but 49 sec. ahead of Wimille on the best Bugatti. The last named then had carburetter trouble, leaving the challenge to Nuvolari, who had made a bad start.

Stuck broke his own car early in the race and took over the Auto-Union of Prince Leiningen, with which he raised the lap speed to nearly 102 m.p.h., but this took place too late to affect the major issue, Caracciola coming in second 53 sec. behind Fagioli and 24 sec. ahead of Nuvolari. Once again Alfa Romeo were completely outclassed.

In the last race of the year neither Bugatti nor Alfa Romeo could keep in sight of the German cars on the fast, but rough, Brno circuit used for the Czechoslovak Grand Prix. Fagioli averaged 82.9 m.p.h. and put in the best lap but was deprived of his position by a pit stop, leaving Stuck the winner at an average speed of 79.11 m.p.h. Nuvolari brought a six-cylinder 3.7-litre Maserati into third position and Varzi was placed fifth in an Alfa Romeo. Practice for this event was notable for the appearance of Nuvolari at the wheel of an Auto-Union, and although he remained faithful to Italian cars for a further three racing seasons he must have realised that the threat of German supremacy was soon to be established as a fact.

Seldom can the fortunes of any make have suffered such an utter change of fortune as Alfa Romeo in 1934. The P.3 models were beaten twice only between their introduction for the Italian Grand Prix early in 1932 and the end of 1933. The positions

of the P.3 B type cars are vividly shown in the table set out below in which the best position for any make of car is given for the major races of the year.

1934 RESULTS BY MAKE OF CAR

Event	*Alfa Romeo*	*Bugatti*	*Maserati*	*Auto- Union*	*Mercedes-Benz*
Monaco	First	Third	Second	N.S.	N.S.
Eifel Races	Third	N.S.	N.S.	Second	First
French G.P. . .	First	Fourth	Retired	Retired	Retired
Marne G.P. . .	First	N.S.	Retired	N.S.	N.S.
German G.P. . .	Third	N.S.	Fourth	First	Second
Belgian G.P. . .	Retired	First	N.S.	N.S.	N.S.
Coppa Acerbo . .	Fourth	Third	Second	Fifth	First
Swiss G.P.	Fourth	Third	Eighth	First	Sixth
Italian G.P.	Third	N.S.	Fifth	Second	First
Spanish G.P. . .	Fifth	Third	N.S.	Fourth	First
Czechoslovak G.P.	Fifth	Retired	Third	First	Second

It is immediately apparent that Maserati had a thoroughly bad year and that from the French Grand Prix onwards Bugatti staged something of a come-back. In the last half of the season, however, it is clear that the superior power of the German cars was giving them continuous victories. They were not, in fact, defeated from the 1st July onwards, and only Moll on the Alfa Romeo at Pescara contrived to put up a record lap when the German cars were running.

There was little to choose between the successes of the two rival German manufacturers, and the Nazi prize fund was divided between them. By this time, however, the construction and operation of advanced designs of their kind involved expenses far beyond anything which had previously been thought possible in road racing and the prize fund money was but a tithe of the burden borne by each constructor.

CHAPTER TWELVE

Teutonic Triumphs

RACING STATISTICS 1935-36

Date	*Event*	*Course*	*Driver*	*Car*	*Average Speed m.p.h.*	*Fastest Lap m.p.h.*
22/4/35	Monaco G.P.	Monte Carlo	L. Fagioli	Mercedes-Benz	58.17	60.08*
5/5/35	Tunis G.P.	Carthage	A. Varzi	Auto-Union	101.2	105.17*
10/6/35	Eifel Races	Nürburg Ring	R. Caracciola	Mercedes-Benz	72.8	75.6*
17/6/35	Penya Rhin G.P.	Montjuich	L. Fagioli	Mercedes-Benz	66.99	—
17/6/35	,,	,,	R. Caracciola	Mercedes-Benz	—	68.94*
23/6/35	French G.P.	Montlhéry with chicanes	R. Caracciola	Mercedes-Benz	77.39	—
23/6/35	,,	,,	T. Nuvolari	Alfa Romeo	—	85*
7/7/35	Marne G.P.	Rheims	R. Dreyfus	Alfa Romeo	98.03	102*
14/7/35	Belgian G.P.	Spa	R. Caracciola	Mercedes-Benz	97.8	—
14/7/35	,,	,,	M. von Brauchitsch	Mercedes-Benz	—	103.7*
28/7/35	German G.P.	Nürburg Ring	T. Nuvolari	Alfa Romeo	75.43	—
28/7/35	,,	,,	M. von Brauchitsch	Mercedes-Benz	—	80.73*
4/8/35	Coppa Ciano	Montenero	T. Nuvolari	Alfa Romeo	55.18	56.22
15/8/35	Coppa Acerbo	Pescara	A. Varzi	Auto-Union	86.6	90.9*
25/8/35	Swiss G.P.	Berne	R. Caracciola	Mercedes-Benz	89.95	--
25/8/35	,,	,,	L. Fagioli	Mercedes-Benz	—	99.5*
8/9/35	Italian G.P.	Monza 2.68 Miles	H. Stuck	Auto-Union	86.2	—
8/9/35	,,	,,	T. Nuvolari	Alfa Romeo	—	90.77*
22/9/35	Spanish G.P.	San Sebastian	R. Caracciola	Mercedes-Benz	101.92	—
22/9/35	,,	,,	A. Varzi	Auto-Union	—	108.11*
29/9/35	Czechoslovak G.P.	Brno	B. Rosemeyer	Auto-Union	82.39	—
29/9/35	,,	,,	A. Varzi	Auto-Union	—	85.21*
13/4/36	Monaco G.P.	Monte Carlo	R. Caracciola	Mercedes-Benz	51.69	—
13/4/36	Monaco G.P.	Monte Carlo	H. Stuck	Auto-Union	—	56.01*

Racing Statistics 1935-36 (continued)

17/5/36	Tunis G.P.	Carthage	R. Caracciola	Mercedes-Benz	99.62	—
17/5/36	,,	,,	B. Rosemeyer	Auto-Union	—	103.79*
7/6/36	Penya Rhin G.P.	Montjuich	T. Nuvolari	Alfa Romeo	69.21	71.85*
14/6/36	Eifel Races	Nürburg Ring	B. Rosemeyer	Auto-Union	72.71	74.46
21/6/36	Hungarian G.P.	Budapest	T. Nuvolari	Alfa Romeo	69.1	71.84*
28/6/36	Milan Circuit	Milan	T. Nuvolari	Alfa Romeo	60.02	—
28/6/36	,,	,,	A. Varzi	Auto-Union	—	62.26*
26/7/36	German G.P.	Nürburg Ring	B. Rosemeyer	Auto-Union	81.8	85.52*
2/8/36	Coppa Ciano	Leghorn	T. Nuvolari	Alfa Romeo	74.8	77.05
15/8/36	Coppa Acerbo	Pescara	B. Rosemeyer	Auto-Union	86.48	—
15/8/36	,,	,,	A. Varzi	Auto-Union	—	89.04
23/8/36	Swiss G.P.	Berne	B. Rosemeyer	Auto-Union	100.45	105.42*
13/9/36	Italian G.P.	Monza with chicanes	B. Rosemeyer	Auto-Union	84.59	87.18*
12/10/36	Vanderbilt Trophy	Roosevelt Speedway	T. Nuvolari	Alfa Romeo	65.99	69.92*(P)

Note.-In 1936 Czechoslovak and Spanish G.P. not held ; Belgian, Marne and French G.P. for sports cars.
* Record

THE latter half of 1934 had been an unbroken run of successes for the newly designed German cars with all independent suspension and engines developing 300 b.h.p. or more. The margin by which these victories had been won was nevertheless extremely small and measured either by race averages or fastest lap speeds was of the order of 2 per cent or less.

The companies who were continuing with established designs of cars, that is to say Alfa Romeo, Bugatti and Maserati, had, therefore, to decide whether they should scrap their previous experience and build new types of cars or endeavour to bridge the relatively small gap by improving their existing models. All three adopted the latter course, engineering counsels being doubtless swayed by financial considerations. Alfa Romeo made more detail changes than the others, enlarging their P3 engine to 3.2-litres capacity, changing to independent suspension of the Dubonnet type at the front with reverse quarter-elliptic springs in the Bugatti style at the rear.

Maserati at first confined themselves to the six-cylinder engine of 3.7-litres capacity in their existing chassis, which had gained first places at Modena and Naples, and ran third at Brno in 1934, and Bugatti decided that his best course was to get the 3.3-litre cars going really properly.

Mercedes-Benz also made practically no change in the chassis design of their cars, but towards the end of 1934 they had fitted a power unit in which the swept

volume had been increased from 3.7 to 3.99 litres, by changing the bore and stroke from 82 x 88 mm. to 82 x 94.5 mm. The result was to raise the power from 398 to 430 b.h.p. at 5,800 r.p.m., figures comparing very favourably with the 302 b.h.p. which was given by the 78 x 88 mm. engine during its early trials.

Auto-Union introduced more substantial modifications. The bore of the sixteen-cylinder engine was increased from 68 to 72.5 mm., and the stroke remained the same at 75 mm. ; the compression ratio was increased from 7 : 1 to 8.95 : 1 ; maximum engine revolutions were raised from 4,500 to 4,800 r.p.m., and output rose from 295 to 375 b.h.p. There was, therefore, a gain both in swept volume (from 4.36 to 4.95 litres), and output per litre. The chassis design was also changed in one important feature-the transverse rear springs used with the swing axle in 1934 were discarded in favour of links connecting to torsion bars within the tubular frame members. The car was also markedly changed in appearance by modifying the tail of the body and fitting stub exhaust pipes to each cylinder, in place of delivery into a tail pipe on each side.

Neither Auto-Union nor Bugatti entered the opening formula event at Monaco, and although a Mercedes-Benz, driven by Fagioli, won, it was no easy victory. The new six-cylinder Maserati, driven by Etancelin, not only proved faster than the Alfa Romeos, but displaced the Mercedes-Benz driven by Caracciola from second position, and although as a result of fierce driving the Maserati brakes weakened so much that it was only able to finish fourth, Caracciola's car broke down so that in the end an Alfa Romeo ran second.

When the Tunis Grand Prix was run in 1932, a Type 51 Bugatti, driven by Varzi, had won at 90.28, and another in the hands of Chiron had lapped at 93.8 m.p.h. In 1935 Varzi was having his first year with Auto-Union and this company relied solely upon him to repeat his previous victory. In this they took a well-judged risk, for with a 5-litre engine he had no difficulty in beating the 3.3-litre Bugattis, Scuderia Ferrari Alfas and Maseratis. One of the former, driven by Wimille, ran in second place throughout with a Maserati, confined to top gear, third. Comotti was fourth on a team Alfa and various older Alfas driven by relatively inexperienced drivers filled fifth and subsequent positions.

The Eifel Races on the Nürburg Ring were held in June, and as usual the German teams were there in force. Auto-Union had discovered a new star in B. Rosemeyer, an ex-motor-cyclist, who showed his skill by coming home only 2 sec. after the Mercedes-Benz of Caracciola despite finishing on only fourteen cylinders. Caracciola made the fastest (and new record) lap, but Rosemeyer showed that, perhaps, it was no disadvantage to approach the driving problems of unorthodox rear-engined racing cars with a mind unclouded by experience of orthodox types.

An Alfa Romeo finished third in the race with Chiron at the wheel. This make, with Nuvolari driving, also ran third in the Penya Rhin event, which Fagioli was permitted to win for Mercedes-Benz with Caracciola second.

Auto-Unions stood down for the Spanish race as they were busy correcting various troubles which presented themselves in the Eifel event and wished to have the cars perfected before the French Grand Prix at Montlhéry. This course now suffered the indignity of a chicane placed upon the straights so as to reduce average speeds, and

in the hopes of repeating their victory of the previous year, Alfa Romeo enlarged the engine capacity of their cars to 3.5 litres. Bugatti also increased the cylinder capacity of his cars to 3.8 litres, but as was so often the case the single entry from this works was one of those assembled too late to become a serious competitor.

The race itself proved clearly that Auto-Unions were still suffering from technical troubles. Varzi, who had put up the fastest practice lap, suffered from continuous plug oiling, Stuck retired after the sixth lap with suspension trouble, Rosemeyer broke his transmission on the sixteenth lap. The first part of the race accordingly resolved itself into an immense struggle between Alfa Romeo and Mercedes-Benz, Nuvolari building up a lead of 8.4 sec. over Caracciola in the first twelve circuits and making the fastest lap of the day. Immediately afterwards the Italian had to retire with piston trouble, allowing the German cars to run first and second two laps ahead of a six-cylinder Maserati.

Mercedes-Benz repeated this victory in the Belgian Grand Prix at Spa, Caracciola again being the winning driver, and Fagioli again at variance with a pit control which asked him to run second when he felt able to move into first position without exceeding the stipulated r.p.m. In protest he handed over his car to von Brauchitsch, who proceeded to break the lap record for the course to finish second despite the time lost in the change-over. Once more an Alfa Romeo, driven by Chiron, finished third, and one of the team of 3.3-litre Bugattis ran fourth.

A week before this event Alfa Romeo had a walk-over at the Marne Grand Prix at Rheims, but no one really expected that they would be serious contenders for the German Grand Prix on the Nürburg Ring. The previous year they had finished no better than third, and although they had been able to repeat this position in the Eifel Races of 1935 it seemed that with both the German teams making every effort to win they were scarcely likely to prove victorious in what was now the most important race of the year. The first five laps confirmed this view of their chances for at this stage one Alfa had retired, Chiron was running fourth, Nuvolari sixth, and no other non-German car better than twelfth. What was to follow was a triumph of man over machinery on a wet road, when driving skill was at a premium. On the sixth lap Nuvolari began to put on speed and between then and the end of the ninth circuit he passed Rosemeyer, Chiron, Brauchitsch, and Fagioli. On the tenth lap he did even better and got past Caracciola, so that on the eleventh (half distance) he was in the lead. He then suffered a grievous misfortune for at his pit stop the hand refuelling pump broke down and an improvised method of replenishing the tank by churns substituted. In consequence he lost 2 min. 14 sec., whereas von Brauchitsch took only 47 sec. On the twelfth lap, therefore, Nuvolari was back in fifth position, but he rose to second on the thirteenth, on which he passed Caracciola, Rosemeyer and Fagioli, and became 1 min. 9 sec. behind von Brauchitsch. The latter pulled away somewhat by making a record average lap of 80.73 m.p.h. on his fourteenth circuit, but then, apparently feeling he had enough time in hand, slowed down to 77.6 m.p.h., 77.5 m.p.h. and 74.9 m.p.h. between the sixteenth and eighteenth laps. Nuvolari, *per contra*, crowded on speed and averaged 78.9 m.p.h., 79.2 m.p.h. and 79.3 m.p.h. for the same laps. He was, however, never able to make up more than 16 sec. a lap on Brauchitsch, and when they started the last circuit was still 35 sec. to the bad. On the face of it a German victory was assured, but the position indicator in front of the grandstand showed that with half a lap to go Nuvolari had got ahead. He crossed the line

2 min. 39 sec. before the Auto-Union, driven by Stuck, who was followed by Caracciola and Rosemeyer. Then, in fifth position, came a weeping Brauchitsch, whose car finished on the rim of the nearside wheel. He had a burst tyre and took 17 min. for his twenty-second lap, but no one could dispute the justice of Nuvolari's victory, for without the misfortune at his pit stop he would not have been out of the lead for the last half of the race.

Nuvolari and Alfa Romeo secured a second successive win at Leghorn in the Coppa Ciano with no other competitors of worth, but in the Coppa Acerbo, on the fast Pescara circuit, Auto-Union competed with a full team. Although a chicane was put on the long straight to reduce maximum speeds the Auto-Unions of Rosemeyer and Varzi were timed over a flying kilometre at 172 and 164.3 m.p.h. respectively, whereas the best speed achieved by Nuvolari was 147.1 m.p.h. This margin was too big to make up, and although Rosemeyer damaged his car in a skid he was able to finish second to Varzi, Alfa Romeos taking third to sixth positions.

This was the second victory of the year for the rear-engined cars, which had yet, however, to beat their German rivals. They met them once more, and were again defeated in the Swiss Grand Prix in which the now almost monotonous result of Caracciola first, Fagioli second, was witnessed, with a lap record by the latter.

Auto-Unions took their revenge in the Italian Grand Prix which was run over an artificial twisty circuit developed by placing five chicanes on the Monza track. At half distance Nuvolari's superb driving skill was paying its usual dividend ; he had made the fastest lap of the day and was in the lead. Unfortunately, his car then broke a piston, and although he took over from his team mate, Dreyfus, who was then lying fourth, he was unable to do more than be runner-up to the Auto-Union of Stuck, whose best lap was 2 min. 50.4 sec., compared to Nuvolari's 2 min. 49.8 sec.

No Mercedes-Benz could better 2 min. 53 sect. ; none of the team of four finished, and only one went more than half distance. Bugatti brought back his 3.3-litre cars but these were quite outclassed, Wimille making the best lap in 2 min. 59.2 sec.

It is worth noting that Nuvolari used an entirely new design of car at Monza, having not only independent springs to the front wheels, but also at the rear with a swing axle and transverse leaf. It had an eight-cylinder engine, 3.8-litre capacity, with one blower and the entire appearance of the car had altered. The P.3 design was now withdrawn from first-class racing.

The Mercedes-Benz disappointment in Italy was compensated by a sweeping one, two, three victory in the Spanish Grand Prix, for although an Auto-Union put in a record lap the highest position occupied by this make in the end was fifth. A 3.3-litre Bugatti driven by Wimille finished fourth, having at one time been as high as third. Nuvolari retired in the eighth lap.

The last race of the year was on the Brno circuit. Mercedes-Benz did not enter it, and Varzi on the Auto-Union gave every appearance of winning, until forced to retire on the twelfth lap. Rosemeyer who had hitherto run second took over the lead and the Alfa Romeo of Nuvolari, which was third, correspondingly went to second place, this being the finishing order,

1935 was definitely a Mercedes-Benz year. They were only beaten twice and only thrice did they fail to make the fastest lap. They were able to achieve this success with 4-litre engines against the opposition of Auto-Union with 4.95-litre power units, but it is true to say that the cornering and road-holding peculiarities of the rear-engined cars were such that no one had yet been able to drive them to full advantage, although Rosemeyer was an obviously promising recruit. Alfa Romeo had relied almost entirely upon Nuvolari, but had secured only one win in races against the German cars.

During 1935 the Italian concern were developing a V.12 4-litre engine and they were confident that with the extra power available from this they would be able to take full advantage of their new independently sprung chassis and reassert in 1936 the supremacy which had been theirs only two seasons before. Maserati also had a V type engine with eight cylinders under development, together with an all independently sprung chassis using torsion bars at the front and semi-elliptic springs at the rear. Bugatti had had a poor year, but confined new projects to a 4.7-litre engine fitted into a modified frame giving a central driving position.

Although more successful than Bugatti, Auto-Union also had a relatively unsuccessful season in 1935, having won only two of the International Grands Prix. For the ensuing year they embarked on considerable design changes without departing from Dr. Porsche’s general concept.

It was found possible to increase the bore and stroke to 75 x 85 mm. without displacing the cylinder centres or increasing the overall weight and dimensions of the power unit, and the capacity was thus enlarged to 6.01 litres. With compression ratio, max. r.p.m., and manifold pressure all increased, the output was raised to 520 b.h.p.

The chassis dimensions were also changed slightly, the wheelbase being increased by some 4 in., which was devoted to a larger tank, fitted as before between the front of the cylinder block and the back of the driver’s seat. The dry weight remained unchanged (and was, of course, still within the formula limit), and the all-round performance of the car enormously increased.

Mercedes-Benz also increased the capacity and output of their racing cars, bore and stroke for 1936 being 86 x 102 mm., giving a capacity of 4.74 litres with an output of 494 horse-power at 5,800 r.p.m. This larger engine was fitted into a new chassis, in which the wheelbase was shortened by some 11 in., the rear axle being considerably modified to cope with the increased engine torque.

The Mercedes-Benz team of drivers was simultaneously strengthened by the engagement of the vastly experienced Louis Chiron, and the works thus had the services of three drivers in the top flight with which to counter the problem of Nuvolari’s special abilities with the Alfa Romeo. Auto-Union continued with Varzi and Stuck as their most experienced drivers, with Bernd Rosemeyer to back them up.

The first formula event of the year was as usual the Monaco Grand Prix, and any comparison with previous events was made impossible by appalling weather conditions and by a multiple crash which eliminated many of the fastest drivers at the outset.

After an early struggle between Nuvolari and Caracciola the latter went into the lead, whilst in the concluding stages Nuvolari was also passed by two Auto-Unions. As might be expected from these conditions the speeds were the slowest since 1930.

Mercedes-Benz then proceeded to contest the Tunis Grand Prix with great success, Caracciola and Chiron being first and second at half distance, to Rosemeyer's third. The Auto-Union driver subsequently speeded up ; then ran into trouble ; so also did Chiron's Mercedes-Benz, and it was the eight-cylinder Alfa Romeo which finished in second position. This race was run in mid-May and from this date forward the Stuttgart firm was to have an unbroken string of failures. Caracciola was beaten by 3 sec. by Nuvolari in the Penya Rhin Grand Prix, and in the Eifel Races, run in June, with shocking weather, Nuvolari and Rosemeyer were first and second well ahead of Brauchitsch and Caracciola at half distance.

During the second half the rain slowly turned to thick mist, so that only Rosemeyer was able to continue at almost undiminished speed and by converting a 9 sec. deficit to a 2 min. 13 sec. lead fully earned the title of *Nebelmeister.* Nuvolari, in second place, was followed by two other Alfa Romeos, Mercedes-Benz being fifth and sixth.

Nuvolari followed this race by beating Mercedes-Benz and Auto-Union at Budapest and Varzi alone at Milan ; the cars were then brought together for the German Grand Prix which was now indisputably the premier event of the year. Mercedes-Benz put in five cars and Auto-Union and Alfa Romeo four each and, interestingly enough, it was to be the youngest drivers of the day who were really to show their worth. Nuvolari could make little headway, and although Caracciola made the fastest lap for Mercedes in 10 min. 4.6 sec., the new-comer Lang ran him close at 10 min. 9.8 sec., and occupied second position from the end of the first to the seventh lap, led on the eighth, and was lying third on the thirteenth, when he retired. But with the exception of the first and the eighth laps (after a refuelling stop), Rosemeyer never moved from the first place. He raised the lap record from 80.73 to 85.52 m.p.h. and the final winning speed from 75.43 to 81.8 m.p.h., a fantastically large margin for a year's development.

Nuvolari drove a twelve-cylinder Alfa at Nürburg, but it was generally thought that it was then not running at its best. It did little better in the next event on the calendar, which was for the Coppa Ciano, run over a new and much faster course outside Leghorn.

On the first lap the latest Alfa had rear axle trouble and the team manager called in an older eight-cylinder car and handed it to Nuvolari, who then passed the whole of the Auto-Union team, which were the same cars which had run a week previously on the Nürburg Ring and were in consequence very tired.

The race has an historic value for it was the last occasion that year when Alfa Romeo finished in front of either Mercedes-Benz or Auto-Union.

The latter had a full team of properly prepared cars available for the Coppa Acerbo on the Pescara Circuit over which two of their cars were clocked at 183 m.p.h. over a kilometre. The 4-litre, twelve-cylinder Alfa Romeo showed a maximum of 152 m.p.h., and in the face of such a tremendous handicap upon the straights the car was doomed to failure. Rosemeyer eventually won by the remarkably large margin of 6 min. from his team-mate Von Delius, and Varzi was third, having suffered a lot of tyre trouble. The latter made the fastest lap, which was a little slower than the speed obtained the previous year.

Rosemeyer won his second race in succession (and three out of four events) at Berne in the Swiss Grand Prix. Mercedes-Benz entered four cars and Bugatti also brought out his new 4.7-litre model with which, however, he had little fortune. Caracciola had made the fastest lap in practice and he kept ahead of Auto-Unions the first eight laps. Nuvolari was also well up, in fact at the end of five laps only fractions of a second separated the leaders. By the tenth lap, however, Rosemeyer was leading Caracciola by 4 sec., Lang in another Mercedes-Benz was third, Varzi in an Auto-Union fourth, Brauchitsch fifth, and Nuvolari sixth, 42 sec. behind. Rosemeyer was taking no chances and broke the lap record on the eleventh and again on the fifteenth circuits, whereas Nuvolari ran into trouble and had to abandon. In the last half of the race all the Mercedes-Benz team had trouble and all three positions were annexed by Auto-Union. Rosemeyer raised the lap record by nearly 5 m.p.h. and the final average speed by 10 m.p.h.

The unorthodox Auto-Union design could only be driven to the limit by a man with altogether abnormally quick reaction times. Rosemeyer proved himself to be such a one and secured his third victory in succession, and the fourth out of five races, in the last European event, held on part of the Monza Circuit. Again he made the fastest lap and again Nuvolari proved a challenger, using the twelve-cylinder Alfa Romeo.

The opening laps were fought out between Stuck on an Auto-Union and Nuvolari, but the former left the road which enabled Rosemeyer to win by a margin of 2 min. 20 sec. from the Alfa.

The last time in which European and U.S.A. cars had run together in Europe was in the 1933 Monza Grand Prix in which Trossi drove a specially constructed 4.43-litre Duesenberg which retired in the first heat. To find any serious competition we have to go back to 1927, in which year two front-drive Millers and a Duesenberg competed in the European Grand Prix at Monza, one of the former coming in a very bad third. But in 1936 Nuvolari had a final, if extra European, win in an unusual race run in the U.S.A. For the first time since the 1914-18 war an international " road " race was run, although on a highly artificial enclosed circuit. It was, in fact, something of a cross between a dirt-track event and a road race in the European understanding of the term, but was dominated by European entries. Nuvolari, to the astonishment of the Americans, scored an exceedingly easy victory at nearly 66 m.p.h. over Wimille on a Bugatti, and also made the fastest lap.

The Vanderbilt Trophy showed how much the road worthiness of U.S.A. racing cars had been neglected, for although in practice Nuvolari lapped 69.92 m.p.h., the fastest of any U.S.A. designed car was at 66.55 m.p.h. No American car finished the race in the first six places, and the highest race average was 60.48 m.p.h.

The years 1935 and '36 had proved fruitful ones for German cars, although it is interesting to observe that in 1935 it was Mercedes-Benz who were virtually all conquering, whereas 1936 was definitely an Auto-Union year, Mercedes-Benz having only two victories at the beginning of the season and ending the year by withdrawing the team which had been entered in the Italian Grand Prix. Maserati and Bugatti virtually disappeared from serious racing during this period, but the combination of Alfa Romeo, plus Nuvolari, was still able to spring surprises ; it is significant that without Rosemeyer's driving for Auto-Union, Alfa Romeo would stand in the records as winners of six out of the thirteen most important races of the year,

The value of these two drivers to their particular companies can be shown by taking the best lap in 1936 on a relatively slow course such as the Nürburg Ring and a very fast one such as at Berne and comparing the times they put up with the next best driver on the same make and type of car. Thus :

1936 LAP TIME VARIATIONS

Course	*Cars and Drivers*			
	Alfa Romeo		*Auto- Union*	
	Nuvolari	*Brivio*	*Rosemeyer*	*Stuck*
Nürburg Ring	10 min. 14 sec.	10 min. 28 sec.	9 min. 56.6 sec.	10 min. 22.6 sec.
Swiss G.P.	2 min. 41.5 sec.	2 min. 45.2 sec.	2 min. 34.5 sec.	2 min. 39.5 sec.

These figures also show that in the 1936 stage of automobile design a super excellent driver on a relatively inferior car was more than a match for a first-class driver on a first-class car ; hence, the tradition of motor racing as a battle between men, as well as a struggle between machines, still had limited validity.

CHAPTER THIRTEEN

Year of Titans

RACING STATISTICS 1937

Date	*Event*	*Course*	*Driver*	*Car*	*Average Speed m.p.h.*	*Lap Speed m.p.h.*
6/6/37	Rio de Janeiro G.P.	Gavea	C. Pintacuda	Alfa Romeo	51.5	—
13/6/37	Eifel Races	Nürburg Ring	B. Rosemeyer	Auto-Union	82.56	85.13
20/6/37	Milan G.P.	Milan	T. Nuvolari	Alfa Romeo	64.4	67.8*
5/7/37	Vanderbilt Cup	Roosevelt Field	B. Rosemeyer	Auto-Union	82.95	—
5/7/37	,, ,,	,, ,,	R. Caracciola	Mercedes-Benz	--	84.5*
11/7/37	Belgian G.P.	Spa	R. Hasse	Auto-Union	104.87	—
11/7/37	,, ,,	Spa	H. Lang	Mercedes-Benz	—	108.8*
25/7/37	German G.P.	Nürburg Ring	R. Caracciola	Mercedes-Benz	82.77	—
25/7/37	,, ,,	,, ,,	B. Rosemeyer	Auto-Union	—	85.57*
8/8/37	Monaco G.P.	Monaco	M. von Brauchitsch	Mercedes-Benz	63.25	—
8/8/37	,,	,,	R. Caracciola	Mercedes-Benz	—	66.99*
15/8/37	Coppa Acerbo	Pescara	B. Rosemeyer	Auto-Union	87.61	92*
22/8/37	Swiss G.P.	Berne	R. Caracciola	Mercedes-Benz	97.42	107.14(P)
12/9/37	Italian G.P.	Leghorn	R. Caracciola	Mercedes-Benz	81.59	84.5*
26/9/37	Czechoslovak G.P.	Brno	R. Caracciola	Mercedes-Benz	85.97	94.89*
2/10/37	Donington G.P.	Donington	B. Rosemeyer	Auto-Union	82.86	85.62*
2/10/37	Donington G.P.	Donington	M. von Brauchitsch	Mercedes-Benz		85

* Record

WHILST the races of 1936 were being contested the terms for a future formula were being argued.

Under the terms agreed in October, 1932, the 750 Kg. maximum weight formula expired at the end of 1936, but. although discussions began on the subject of future rulings in the winter of 1935-36, no decision was agreed until September, 1936. It was by then impossible for constructors to build new cars and have them ready for the ensuing season, and the maximum weight regulations were, therefore, given a further lease of life and remained in force for 1937. During this year, however, design teams were concentrating on 1938 models and there was every temptation to make do with unchanged types for the current year. Mercedes-Benz were an exception in this respect for their 1936 model had proved so disappointing that they were well ahead with a replacement which had an entirely new design of frame and front and rear suspension systems. They were able to graft an eight-cylinder engine of 5.6-litre capacity into this

chassis without exceeding the weight limit and hence, for the first time since the beginning of 1934, they were competing with Auto-Union on an equal footing in respect of engine capacity. Both of these cars were now powered with engines developing over 500 b.h.p. and were capable of some 200 m.p.h. Grand Prix racing in 1937 was, indeed, a struggle between Titans, and it is improbable that racing cars with piston engines will ever again have such incredibly high performance factors, nor make such stringent demands on the skill, the nerve, and, above all, the discretion of the drivers. Of the latter Varzi retired from the Auto-Union team and was replaced by Fagioli, who left Mercedes-Benz. The latter Company added Zehender and Richard Seaman to their number, and with Lang had, therefore, five drivers plus Kautz in reserve.

Alfa Romeo had V12 4-litre cars with independent suspension all round, but as these were giving not more than 400 h.p. they were obviously handicapped on fast circuits. On twisty roads with comparatively low race averages they thought that the skill of Nuvolari would offset the deficiency in engine power, but somewhat ironically, on the first occasion during the year when an Alfa Romeo came into first place it was their second string, Carlo Pintacuda, who was the driver. This was in a race run outside Rio de Janeiro and the Italians beat Stuck on an Auto-Union by a narrow margin of 4 sec., and at the very low average speed of 51.5 m.p.h. Then as late as mid-June, Nuvolari beat a lone Auto-Union, driven by Hasse, on the Milan circuit, the Alfas of Farina and Ruesch being second and third.

Formula racing in Europe started with the Eifel Races on June 13th, run as usual on the Nürburg Ring. On the first lap the new Mercedes-Benz was first, third and fourth, Rosemeyer on the Auto-Union being 5 sec. behind Caracciola who led ; subsequently Rosemeyer went into, and held, the lead and although Mercedes-Benz finished second and third they all experienced fuel pump trouble.

This was Rosemeyer's third successive win on this famous circuit and on this occasion the Alfa Romeo-Nuvolari combination could achieve no better than fifth place.

Auto-Union, Mercedes-Benz and Alfa Romeo each sent two cars to the U.S.A. for the second race of the Vanderbilt Trophy on the Roosevelt Speedway. The organisers had acted upon the criticisms of the track made the previous year and had considerably revised it so as to reduce the number of corners. At the start Caracciola led Rosemeyer, and an American driver, Rex Mays, ran third, driving a 3.8 Alfa Romeo which had been modified by its owner-driver by the addition of a centrifugal supercharger. He held third position for practically the entire race, keeping comfortably ahead of the two official Alfa Romeo entries, but was overwhelmed by Rosemeyer, who won fairly easily at 82.56 m.p.h. Caracciola retired after twenty-two laps, and although Seaman made a brave struggle and finished second, he was as yet too new in this class of racing to cope with his highly experienced rivals. The first American car finished seventh at 67.6 m.p.h., the results thus confirming the technical lessons of the previous year.

There being no transatlantic passenger air service in 1937, participation in the U.S.A. event automatically excluded the cars and drivers running therein from the Belgian Grand Prix run the week following. Nevertheless, remarkable speeds were achieved. The lap record had been set up in 1935 by Brauchitsch on the 4-litre Mercedes-

Benz at 103.7 and was now raised by this same driver on the new 5.66-litre model to 105.6 m.p.h. Stuck, however, on the 6-litre Auto-Union was even faster, doing 107.7 m.p.h. and was timed over a flying kilometre at 175 m.p.h. Fastest of all was the relatively new-comer Lang who put in the eighteenth lap at an average of 108.8 m.p.h. and whose Mercedes-Benz was timed over the kilometre at the astonishing speed of 193 m.p.h. None of these three, however, was destined to be the winner. Stuck had a long stop at quarter distance which dropped him to fifth position after which he recovered to second, von Brauchitsch retired on the eighteenth lap and Lang had a number of stops and finished third. In consequence, it was the relatively unknown Hasse on an Auto-Union who led for almost all the last half of the race to finish at the highest average speed yet realised on this extremely fast and dangerous circuit.

The now all-important German Grand Prix was staged on the Nürburg Ring at the end of July. It is significant that whereas Mercedes-Benz and Auto-Union each entered teams of five cars Alfa Romeo ran only two works' models and no other concern troubled to make a direct entry.

In practice there was intense competition to make the fastest lap, this being eventually achieved by Rosemeyer who, taking abnormal risks, made a circuit at 87 m.p.h. Lang on a Mercedes-Benz took 6 sec. longer and averaged 86.2 m.p.h., whilst the best Alfa Romeo's time was 22.2 sec. longer than the Auto-Unions, the average being 83.9 m.p.h. As usual the best practice lap was not equalled in the race, fastest being Rosemeyer's second at 85.57 m.p.h., Caracciola doing best for Mercedes-Benz at 85.4 m.p.h., and Nuvolari improving slightly to 84.4 m.p.h. Rosemeyer was frustrated in his ambition to secure four successive wins on this track for Auto-Union, as on his fourth lap he hit the side of the road with such violence that he damaged not only a wheel but the hub cap. A stop of 2 min. 28 sec. whilst the wheel was changed dropped him to tenth position and with further stops for tyres on the eleventh and seventeenth laps he could do no better than finish third 61 sec. behind Caracciola, who drove a steady race, never being lower than second from the third lap onwards. Lang led at the start but towards the end damaged a tyre a long way from the pits and dropped to seventh position. This allowed Brauchitsch to finish second, Seaman having been eliminated by a collision with the Auto-Union driver, von Delius, on the sixth lap. Auto-Union secured fifth position with Hasse, but Stuck retired on the seventh lap when running eleventh. Although unable to finish in the first three Nuvolari came in fourth, 4 min. 4 sec. after the winner, and the Alfa Romeo averaged 80 m.p.h., which would have sufficed to bring it into second position the previous year, and a speed better than the lap record of 1934.

Mercedes-Benz had won the Monaco Grand Prix two successive years and they achieved the hat trick with a decisive win in 1937. Nuvolari was absent testing out a new and much lower twelve-cylinder Alfa Romeo. From start to finish the race was the scene of a fantastic duel between two of the new Mercedes-Benz cars driven by Caracciola and von Brauchitsch. In defiance of team orders the latter forced his leader to travel flat out in order to hold a lead of 27 sec. at the end of forty laps ; Brauchitsch then went by, and at the end of sixty laps led by 34 sec. Caracciola then really decided to show what he could do and raised the lap record to 64.98 m.p.h., and shortly afterwards to 66.99 m.p.h. This effort gave him a lead of 26 sec. in the eightieth lap but led to a pit stop during the course of which Brauchitsch passed to win at 63.25 m.p.h.,

that is to say over 3 m.p.h. faster than the previous record for one lap only. Auto-Union had a poor race, Rosemeyer retiring when third and then taking over Stuck's car to finish fourth. He made his fastest lap at 65.2 m.p.h. with Farina doing the best for Alfa Romeo.

Auto-Union supremacy at Pescara in the race for the Coppa Acerbo was now as traditional as a Mercedes-Benz victory at Monaco. In 1937 practice both Rosemeyer and Stuck put up extremely fast times, as did Caracciola, and by the time the race settled down Rosemeyer was in the lead to the accompaniment of a record second lap at 92 m.p.h. and Caracciola was second. Both the leaders had stops for tyres in the eighth lap. Caracciola's car had trouble with its camshaft bearings and was handed over to Seaman who had the engine on fire and eventually finished fifth. Rosemeyer then won at a record speed and Brauchitsch finished second.

The performance of the new Alfa Romeo was a great disappointment, it retired early in the event, and was withdrawn from participation in the Swiss Grand Prix at Berne the following week. This race was run over wet roads and the remarkable speeds put up by the Auto-Unions the previous year remained unequalled, although in practice both the Mercedes-Benz and the Auto-Union broke the existing lap record with speeds of 107.14 and 106.8 m.p.h. respectively, the drivers being Caracciola and Rosemeyer. In the race the former led throughout and the latter had to be content with making the fastest lap average of 104.7 m.p.h. after he had run off the road and ditched his car in the first lap and had taken over from Nuvolari on the eighth lap. The Italian had practised on one of these rear-engined cars before the 1934 Czechoslovak Grand Prix at Brno. In the Swiss Grand Prix he made no effort to do more than familiarise himself with the cars and after losing No. 6 on the entry list he took over No. 4 from Fagioli, and finished seventh. Alfa Romeo were in a sorry plight without him, and were placed never better than sixth with their fastest car flagged off three laps in arrear at the end of the race. The best lap of these cars (both twelve-cylinder models) was 100 m.p.h.

The German and Swiss Grands Prix offer examples of races run consistently on one course. The Italian Grand Prix on the other hand, after many years on the full length of the Monza circuit had, since the inception of the 750 Kg. formula, been run on varying sections of it with chicanes. In 1937, tradition was even more strongly violated as the event was run over the Leghorn Circuit which had been used for the Coppa Ciano in the previous year. On this occasion Auto-Union had been slighted by Alfa Romeo as a consequence of poor maintenance and Nuvolari had scored one of his frequent personal triumphs. Twelve months afterwards his Alfa Romeo finished seventh and last, and both Caracciola and Lang got their Mercedes-Benz cars round at 84.5 m.p.h., the former winning under team orders at a speed substantially in excess of Nuvolari's prior lap record. Rosemeyer was fastest for Auto-Union, but since the beginning of the season the Mercedes-Benz Engineering Department had increased the output of their straight-eight 5.66-litre engine by over 75 b.h.p., and this in conjunction with their new stiff frame, soft springing and De Dion type rear axle made them virtually invincible, and Auto-Unions relied upon Rosemeyer producing super-human driving skill in every race. In the Czechoslovak Grand Prix he did this very thing. During the first eight laps Lang ran his Mercedes-Benz off the road trying to keep up with him and even a record lap by Caracciola at 94.89 m.p.h. was insufficient to put him into first position, although Rosemeyer did no better than 92.8 m.p.h. The

leader then over-steered his car into the kerb and bent the wheels so badly that he could no longer continue, but after walking 1½ miles to the pits he took over the only other car in the team that was running and passed Seaman to finish third. Caracciola had no difficulty in finishing first.

The last formula race for 1937 and *ipso facto* the last of the 750 Kg. formula was run in England over the road circuit in Donington Park. Auto-Union ran three and Mercedes-Benz four cars, which were the only modern types on the course. Von Brauchitsch, indicated that Mercedes-Benz were the fastest cars by putting in a practise lap at 86.01 m.p.h., the best Auto-Union doing 85.36 m.p.h. with Rosemeyer at the wheel. It is a matter of interest that a Maserati which had raced under the same formula in 1934 lapped at 77.59 m.p.h. In the beginning part of the race two Mercedes-Benz, driven by Lang and Brauchitsch ran first and second with Rosemeyer third, but the former had trouble with his front suspension system and withdrew, so that at half distance, when all the leading cars had made stops for tyres and petrol, Brauchitsch led Rosemeyer by 24 sec. In the second part of the race Brauchitsch was the first of the two leaders to make a routine pit stop and he refuelled and changed both rear tyres in 31 sec. on the fifty-second lap. Rosemeyer delayed his stop until the sixty-second lap and took 32.8 secs. for the same operation, but on the previous circuit the whole aspect of the race had been changed when Brauchitsch lost the tread from a front tyre and had to cover over half a mile at reduced speed as well as losing 28 sec. for the unexpected wheel change. Following this he could win only by making up a deficit of 31 sec. in the last seventeen laps. That is in less than 45 miles. So far from so doing he actually finished 37.8 sec. behind the Auto-Union with Caracciola third. The latter had a no-trouble. trip, but appeared to misjudge the pace at which the race would be run. His steadier driving took him through with only one pit stop, but the advantage he so gained was insufficient in the face of the brilliance of his two young rivals, who tied for fastest lap during the race.

The 1937 results show that Mercedes-Benz reasserted their technical superiority. They were sufficiently enterprising to develop an entirely new eight-cylinder engine for this season alone and with it they had a gross power output much exceeding the larger Auto-Unions with their V-type, rear-mounted power units. The combination of 20 per cent more power with a stiff frame and De Dion rear suspension gave them a superior performance on corners coupled with equal or greater speed on the straight.

In the Monaco and Swiss Grands Prix Mercedes-Benz filled the first three positions, in the German, Italian and Czechoslovak Grands Prix they ran first and second. Auto-Unions, on the other hand, had only one race, the Belgian Grand Prix, in which they filled the first two positions, all their other victories being single-handed efforts by the prodigy, Bernd Rosemeyer.

It will be clear from this brief summary that Alfa Romeo were by now completely out of the picture. In European races they had to be content with fourth in the German Grand Prix and fifth in the Czechoslovak and Belgian Grands Prix. The temporary collapse of Mercedes-Benz in 1936 had, in fact, resulted in an over-estimation of Italian merit, and during 1937 so far from narrowing the gap, Alfa Romeo fell farther behind. This was only to be expected in view of the immense difference in the resources available as between the German constructors and the rest of the world. By 1937 the German teams travelled with imperial pomp accompanied by a great

cavalcade of mobile workshops, spare cars, engines, tyre technicians, carburetter experts and so on. At the factory resources equivalent to a good sized works were constantly available for the racing teams alone, and both companies could draw on the exclusive services of 300 skilled men at any time if they so desired. The cost amounted to approximately £¼mil. in the case of each company and was justified not only by the direct technical and advertising benefits accruing to the companies themselves but also by the immense value as propaganda for the German industry and the Nazi way of life.

The four racing seasons of the 750 Kg. formula had started as a struggle between Auto-Union and Mercedes-Benz ; Alfa Romeo and Maserati ; and Bugatti. By 1936 only three cars counted, the two German makes and Alfa Romeo. 1937 saw the virtual elimination of the last named as a serious competitor and the stage was now set for a 3-litre formula which was to be a demonstration of absolute German superiority.

CHAPTER FOURTEEN

Absolute Supremacy

RACING STATISTICS 1938-39

Date	*Event*	*Course*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Fastest Lap m.p.h.*
10/4/38	Pau G.P.	Pau	R. Dreyfus	Delahaye	54.64	—
10/4/38	,,	,,	R. Caracciola	Mercedes-Benz	—	57.86*
23/4/38	Cork G.P.	Carrigrohane	R. Dreyfus	Delahaye	92.5	95.71*
3/7/38	French G.P.	Rheims	M. von Brauchitsch	Mercedes-Benz,	101.3	—
3/7/38	,,	,,	H. Lang	Mercedes-Benz	—	105.87*
24/7/38	German G.P.	Nürburg Ring	R. Seaman	Mercedes-Benz	80.75	83.76
31/7/38	Coppa Ciano	Leghorn	H. Lang	Mercedes-Benz	85.94	89.17*
31/7/38	,,	,,	M. von Brauchitsch	Mercedes-Benz	—	89.17*
14/8/38	Coppa Acerbo	Pescara	R. Caracciola	Mercedes-Benz	83.69	—
14/8/38	,,	,,	L. Villoresi	Maserati	—	87.79
21/8/38	Swiss G.P.	Berne	R. Caracciola	Mercedes-Benz	89.44	—
21/8/38	,,	,,	R. Seaman	Mercedes-Benz	-	103(P)
11/9/38	Italian G.P.	Monza with chicane	T. Nuvolari	Auto-Union	96.7	—
11/9/38	,,	,,	H. Lang	Mercedes-Benz	—	101.38*
22/10/38	Donington G.P.	Donington Park	T. Nuvolari	Auto-Union	80.49	83.71
2/4/39	Pau G.P.	Pau	H. Lang	Mercedes-Benz	56.09	—
2/4/39	,,	,,	M. von Brauchitsch	Mercedes-Benz	—	57.83
21/5/39	Eifel Races	Nürburg Ring	H. Lang	Mercedes-Benz	84.14	86*
26/6/39	Belgian G.P.	Spa	H. Lang	Mercedes-Benz	94.39	109.12
9/7/39	French G.P.	Rheims	H. Müller	Auto-Union	105.25	—
9/7/39	,,	,,	H. Lang	Mercedes-Benz	—	114.87*
23/7/39	German. G.P.	Nürburg Ring	R. Caracciola	Mercedes-Benz	75.12	81.66
20/8/39	Swiss G.P.	Berne	H. Lang	Mercedes-Benz	96.02	—
20/8/39	,,	,,	R. Carraciola	Mercedes-Benz	—	104.32
3/9/39	Yugoslav G.P.	Belgrade	T. Nuvolari	Auto-Union	81.21	83.9*
3/9/39	,,	,,	M. von Brauchitsch	Mercedes-Benz	—	83.9*

* Record

THE formula (agreed in September, 1936) to have effect in 1938, '39 and '40 was based on a sliding scale relationship between engine c.c. and minimum weight and assumed the equivalent capacity of a supercharged engine to be two-thirds that of an unblown type. The minimum engine size permitted was 666 c.c. supercharged, the maximum 4½-litre unsupercharged, but as frontal area does not vary in relation to engine size and as the fixed items-drivers, wheels, tyres, etc.-form an increased handicap on the smaller sizes of engine everything indicated that constructors would choose the largest swept volume in one of the two categories. Informed opinion held that a 3-litre supercharged engine would be clearly superior to any possible 4½-litre atmospheric induction competitor and hence no surprise was registered when it became known that Alfa Romeo, Auto-Union and Mercedes-Benz had all fitted superchargers to short stroke, high r.p.m., 3-litre power units.

Alfa Romeo introduced an entirely new car, the type 308, having an eight-cylinder engine with virtually the same dimensions as the celebrated P.3 Type B which they had used in 1934. Over 300 b.h.p. at 6,000 r.p.m. was claimed for this design, which was fitted into the new low chassis with all independent suspension which had housed a V.12 engine in the Coppa Acerbo and Italian Grand Prix of the previous year. Alternative V-type engines with twelve and sixteen cylinders were available, the former having a bore and stroke of 63 x 73 mm. (for which an output of 320 b.h.p. was claimed), and the latter cylinders 58 x 70 mm. which had an estimated 350 b.h.p.

Auto-Unions produced a new rear-engined car similar to those used in the previous four years, but of entirely new design. Dr. Porsche was no longer employed as a consultant so that the new car was designed under the direction of technical director Werner, engineer Fuereisen and developed by Eberan von Eberhorst. The tubular frame and Porsche type trailing link I.F.S. were retained, but the steering geometry improved and a De Dion type suspension system was substituted for swing axle at the rear. The engine was a 90 degree V.12 in place of the 60 degree V. 16, and the greater spread of the cylinders made it impossible to continue the ingenious valve gear layout, using only one camshaft, characteristic of the Porsche model. The new engine had a single camshaft operating the inlet valves in both blocks with separate exhaust camshafts on the outer side of each block. As a result of the shorter engine and as a consequence of replacing the fuel tank behind the driver by a pair placed outside the frame members it was possible to bring the driver's seat a good deal farther back on the frame, a change that did not greatly affect the weight distribution but did give a somewhat more orthodox view of the road which, it was thought, would help the drivers to raise lap speeds.

The Auto-Union driving team suffered a tragic, irreparable, loss in February, 1938, when the brilliant Bernd Rosemeyer was killed in a record attempt on the Frankfurt-Darmstadt Autobahn. This blow was the more serious since Stuck had officially left the team and this threw the whole burden of responsibility on the relatively inexperienced R. Hasse and H. Müller, who were reinforced by C. Kautz, who had had occasional drives for Mercedes-Benz. To meet this situation Stuck was prevailed upon to return, whilst for the German Grand Prix and subsequent races the company had the good fortune to secure the services of the incomparable Nuvolari. The loss of Rosemeyer was, however, a grievous handicap in developing the cars through their early tests.

The Mercedes-Benz picture was by contrast a bright one. They had three top-notch drivers, Caracciola, von Brauchitsch and Lang, with Seaman as a recruit of the highest order. The cars were based on the 1937 chassis, the frame and rear suspension of which were retained unchanged and with only minor modifications to the front suspension and transmission. A V.12 engine was used but this again was no novelty, for in 1936 and 1937 engines of this kind having between 5- and 6-litre capacity had been used for record breaking and non-formula races at A.V.U.S.

Both the German cars had over 400 b.h.p. available.

Bugatti decided to make a limited return to racing with a straight-eight 3-litre engine in the latest type chassis with central driving position, which had had a brief run in the 750 Kg. formula, and in addition two French constructors, Delahaye, with a V.12 engine, and Talbot, with a six-cylinder power unit, decided to demonstrate the possibilities of *circa* 200 b.h.p. from 44 litres without supercharger.

One of these unblown types created something of a sensation by winning the first race of the new formula held over a winding circuit at Pau in April. Auto-Unions were not ready to start in this event and the full Alfa Romeo team of three cars was withdrawn after Nuvolari had found his car on fire, caused by a flexing chassis, which had split the fuel tank. The driver suffered from burns and shock and this was his last appearance for the Italian company. Before this mishap practice had shown that Nuvolari and the 4½-litre twelve-cylinder Delahaye were both equal in speed to the 3-litre, supercharged Mercedes-Benz, two of which were entered. The car driven by Lang, however, had to be withdrawn before the race started, and at half distance Caracciola had gained only 6 sec. from Dreyfus on the Delahaye. The enormous fuel consumption of these new, highly supercharged types now became evident, for within less than ninety miles the German car had to call at the pits to refuel. This took only 50 sec., but was sufficient to let the French car go into the lead, and with Mercedes-Benz experiencing subsequent trouble with the gear change the Delahaye won by a lap.

This was the first French win in a major race since the Belgian Grand Prix of 1934, and it was followed by a second victory for the same marque in the Cork Grand Prix a fortnight later. In this event Bugatti also entered one car, driven by Wimille, and this put up the fastest speed over a measured kilometre at 147.25 m.p.h., Dreyfus doing 145 m.p.h. and Bira on a 1934 Maserati, originally built for the 750 Kg. formula, 138 m.p.h. Dreyfus' Delahaye made the fastest lap and with the Bugatti suffering from misfiring he had no difficulty in keeping ahead of the old Maserati despite slowing down for the last few laps.

Neither of the traditional non-formula A.V.U.S. and Eifel Races was held and it was therefore comparatively late in the year that Auto-Unions and Mercedes-Benz came into competition in the French Grand Prix held on the Rheims circuit, which had for many years been the scene of the Marne Grand Prix. The fastest lap so far recorded had been 101.9 m.p.h. by the P.3 Type B Alfa Romeo, but in 1938 practice this speed was exceeded by four Mercedes-Benz drivers and three Auto-Unions, the best figures being Mercedes-Benz (H. Lang) 109.6 m.p.h., Auto-Union (C. Kautz) 107.4 m.p.h., and then, very much slower on this type of course, a 4½-litre six-cylinder Talbot (R. Carriere) at 98.4 m.p.h. Mercedes-Benz entered only three cars and this led to Seaman standing down, although he had made the second fastest lap in practice.

Auto-Union also entered three cars, but only two started. This team had considerable misfortune in practice, for a fully streamlined car devised for this very fast course was overturned by Hasse, and Müller crashed on one of the more normal types and had to go to hospital. Thus only Kautz and Hasse came to the starting line and both crashed before finishing the first lap. The single Bugatti retired at the pits with a broken oil pipe, and so, from the second lap onward, the race degenerated into a high speed tour with three Mercedes-Benz in the lead by so great a margin of speed over the unblown cars that they could take things easily and yet win by fifty miles. Lang made the fastest lap of the race at 105.84, and von Brauchitsch won at a speed almost equalling the previous lap record.

Much of the Auto-Union trouble at Rheims was due to improper shock-absorber settings, but practice for the German Grand Prix showed that the cars as a whole were still far from ready for serious racing.

Alfa Romeo ran a team, but Nuvolari appeared as senior driver for Auto-Union. It was the third occasion on which he had driven a rear-engined car, but it was apparent that he had not immediately mastered the specialised handling problems involved, for his best lap was at 80.5 m.p.h., whereas von Brauchitsch on a Mercedes-Benz put in a practice lap of 86.6 m.p.h. As in the French race, so in the German, the first lap may be considered decisive for Nuvolari damaged his car in a skid and had to retire on the second circuit. By the third lap all the Alfa Romeo cars were out of the picture and the Mercedes-Benz driven by Lang was experiencing ignition trouble. This left Seaman chasing von Brauchitsch. On lap six the Englishman made the fastest circuit of the day, on the seventh he went into the lead (whilst Brauchitsch had both wheels changed in 44 sec.), and on the eighth came in for his own refuel and tyre change, which was accomplished in 52 sec. This put him back into second position again. The two rivals maintained their relative stations until the sixteenth lap, when they both came in to refuel, which they were doing at intervals of 113 miles on cars which carried 70 gallons of fuel. The pressure pumps were capable of delivering this volume in 60 sec. and the tanks had small windows so that the mechanic could gauge the cut-off point. This was misjudged on Brauchitsch's car and led to a large gallonage overflowing. The car was not pushed clear before restarting and a moment after the portable electric starter was engaged the car was a mass of flames immediately in front of Seaman, who was just about to get away. Seaman was only slightly impeded and after a stop of 68 sec. he took a lead from which he was never displaced. Lang took over Caracciola's car and finished second; Nuvolari took over Müller's Auto-Union and finished fourth. Stuck took third place with his Auto-Union, but was almost nine minutes slower than Seaman.

From the Coppa Ciano Auto-Union stood down and this allowed Mercedes-Benz to win with the greatest of ease from both the eight- and twelve-cylinder Alfa Romeos, Lang and Brauchitsch tying for fastest lap. Lang won after Brauchitsch had gone over the line first only to be disqualified for receiving outside assistance after a slight accident.

The principal feature of the day's racing was the astonishing performance put up by Count Trossi on a new 3-litre straight-eight Maserati with a conventional rigid rear axle. He had made best practice time on each day, and on the fourth lap passed from third to first position. This, however, led to engine trouble and it is likely that

the German cars had something in reserve as their best lap in the race was better than anything they achieved during the practice periods.

Auto-Union had taken first position in the Coppa Acerbo in the previous three years and they tried during the interval provided by the Leghorn race to get their cars into full racing condition for this event. But although Nuvolari was clearly mastering his new mount they failed again through mechanical troubles. A Mercedes-Benz finished first and the twelve-cylinder Alfa which had been awarded second place at Leghorn was second again at Pescara. A Maserati made the fastest lap of the day so the Italian crowd was not too ill pleased.

With more than half of the season’s races completed it was evident that although the new highly supercharged 3-litre cars were almost equal in speed to their 6-litre predecessors (Caracciola was timed at 170.90 m.p.h. at Pescara), they were by no means equal in reliability, so that often the Germans were achieving victory with only one car running at the finish.

The Swiss Grand Prix showed that the minor troubles of the Mercedes-Benz team were well on the way to being sorted out, but that Auto-Union were still not clear of their problems. Seaman proved that he was worthy of his win in the German Grand Prix by making fastest practice lap at a speed of 103 m.p.h. and Stuck was fastest for Auto-Union at 100.2 m.p.h. The best Alfa Romeo speed was 99.5 m.p.h.

The race was run in heavy rain, Caracciola had long been acknowledged *Regenmeister,* and although Seaman held the lead for many laps and made the fastest circuit of the day he eventually lost to his team leader by 24 sec. Brauchitsch completed the Mercedes-Benz triumph by running third. Stuck and Farina ran fourth and fifth on an Auto-Union and Alfa Romeo respectively, and the rest of the field finished far behind. Clearly, however, Auto-Unions were now rapidly improving and they scored their first 1938 win in the Italian Grand Prix held in mid-September.

After the previous year’s excursion to Leghorn the race returned to Monza (on which track an entirely artificial course had been marked out with chicanes) and for once it was Mercedes-Benz who had an exceedingly poor day. Caracciola on his second lap made one of his very rare errors of judgment, hit a chicane and stopped his engine. Although he restarted the car, it suffered during the race from over-heating. On the seventeenth lap Seaman’s car caught fire and shortly afterwards Lang and Brauchitsch also retired. At one time it looked as though Auto-Union would be first, second and third, but Stuck ran off the road and two laps from the finish Müller had engine trouble. This left Nuvolari with an easy win over Farina’s Alfa Romeo, with Caracciola a poor third, over ten minutes behind the winner. Lang, however, had made the fastest lap and it remained arguable that the Mercedes-Benz was the fastest racing car of the year.

The Donington Grand Prix in England showed the real merit of the 1938 version of the rear-engined car. Auto-Union had won this race the previous year, aided somewhat by an unlucky tyre failure which put Brauchitsch out of the lead. In the 1938 race there were two Auto-Unions and four Mercedes-Benz cars in the best six practice times and one of the latter made absolutely the fastest time. In the race itself, however, Nuvolari made the fastest lap, and either he or Müller held the lead up to the thirty-second lap. Half distance (forty laps) saw Müller first, Lang on a Mercedes-Benz second, and Nuvolari third ; but these places had been decisively affected by an incident on the thirtieth lap when the engine of Hanson’s Alta disintegrated and dropped oil

over the track, so that on the thirty-first lap a number of drivers lost control and left the road. Seaman, who had been second, became sixth, and Hasse on an Auto-Union retired. After refuelling Lang went into the lead, but suffered from a broken windscreen and was unable to respond to a great spurt made by Nuvolari from the fiftieth lap onwards. At this point Lang was 58 sec. ahead of the Auto-Union, but by the end of the sixty-seventh lap he was 2 sec. behind. Whilst Nuvolari was getting past both Müller and Lang, Seaman's Mercedes-Benz also overtook Müller's Auto-Union and, in fact, although handicapped by his skid, the Englishman actually made up 42 sec. on Nuvolari in the latter half of the race and took third place.

In this last event of 1938 the Auto-Unions proved that they were not only quicker at accelerating away from slow corners (a quality in which they had always excelled), but could also pass the Mercedes-Benz on the straight. During the winter of 1938-39, therefore, the Stuttgart engineers carried out some substantial revisions in design. The appearance of the cars was considerably altered by widening the base of the body so as to enclose all the suspension links, lengthening the nose of the car and placing the radiator farther forward. There was a completely novel type of brake drum and, perhaps most important, a new relation of the two Roots blowers so that instead of supercharging in parallel they compressed the mixture in series thereby reducing the power lost in driving the blowers and raising the engine output from 420 b.h.p. obtained at the beginning of 1938 to over 480 b.h.p. in 1939.

As in 1938 the earliest meeting was at Pau. This was scarcely the type of course on which the cars could show their improvements to the fullest advantage, but this time they made no mistake about winning, although the fastest lap was actually slightly below that put up by the unsuccessful Caracciola in the previous year.

In Eifel Races at Nürburg some astonishing speeds were achieved. In practice Mercedes-Benz made the three fastest times, Lang lapping at 86 m.p.h., and von Brauchitsch and Seaman 85 m.p.h. Nuvolari was fastest for Auto-Union but at the much slower speed of 84 m.p.h., whilst the fastest unsupercharged car, a 4½-litre Talbot put up a speed of 72.6 m.p.h. Mercedes-Benz were never displaced from the lead in the race, which was won by Lang who also repeated his practice lap record and then set up a faster race speed with his 3-litre than had been achieved by any of the 650 b.h.p. 5.6-litre models. Caracciola ran third and Brauchitsch fifth, Seaman failing on the first lap with clutch trouble. All the Mercedes-Benz team had to stop for fuel and tyres, even the steady-driving Caracciola being unable to travel more than 85 miles, although the fuel tanks of the cars had now been enlarged to 88 gallons. Nuvolari had a non-stop race and finished, although slower on lap speeds, only 12 sec. behind the winner.

The Belgian Grand Prix witnessed a second victory for Lang, but tragedy for the Mercedes-Benz team. The race was run under exceptionally difficult conditions with intermittent and local rain showers producing unpredictable slipperiness on the high speed corners which abound on the Spa Circuit. Even Caracciola was caught out and had a minor accident, but worst fate of all befell Richard Seaman who held the lead from the twelfth to the twenty-first laps and then skidded off the wet road surface and damaged the car against a tree. He was temporarily stunned, the large tanks spread fuel on to an inflammable part of the engine and the car burst into flames. An official was unable to release the steering wheel, which had to be detached before the driver could be lifted clear, and by the time he had been dragged out he sustained burns from which he succumbed during the same evening. Before this accident Lang was in second

position, after it he won the race and made the best lap speed. Nuvolari also left the road but was not hurt, Müller broke a valve on his car and Hasse finished second. Of the two Alfa Romeos entered one finished fourth, the other retired at half distance.

The vacancy caused by Seaman's death resulted in only three Mercedes-Benz cars appearing for the French Grand Prix, which was again held at Rheims with four entries from Auto-Union, three from Alfa Romeo, three from Talbot, and two from Delahaye. Once more it was Lang who was prominent in practice. He proved the tremendous speed of the 1939 3-litres, for on the very first day he put in a lap at 117.5 m.p.h. to which Nuvolari replied on the second day with 116.6 m.p.h. on a newly introduced Auto-Union with two-stage boost and 485 b.h.p. Of the unblown cars the fastest pre-race speed was by a Talbot driven by Le Begue, who averaged 105 m.p.h.

The rivalry between Lang, now clearly the fastest of the Mercedes-Benz team, and Nuvolari was continued in most stirring fashion in the event itself. Nuvolari got away to a magnificent start and held the lead for the first three laps, raising the circuit record to 113 m.p.h. in the process. However, at five laps Lang passed to lead by one-third of a second, after which he pulled away to lead by 5 sec. at seven laps, with Nuvolari retiring with a broken engine in the eighth lap. Müller was running only 38 sec. behind, Caracciola had run off the road and retired, so although von Brauchitsch held third position Auto-Unions were placed second, fourth (with Stuck) and fifth, with a new driver, George Meier. At seventeen laps von Brauchitsch retired, and just before he refuelled Lang put on a little extra speed and pulled the lap record up to 114.87 m.p.h. There was no change in order as a result of pit stops and Lang had a 90 sec. lead over Müller until, on the thirty-fifth lap, after a continuous smoking from the engine for some time, his car had to be withdrawn with mechanical trouble. This gave Auto-Union the leading three positions with the best unsupercharged cars some three laps behind. Fate now struck at the rest of the Germans, for Stuck had a long stop at forty laps and drove on at touring speed. Müller, however, had only to continue to win, which he did ; Meier finishing second, one lap (5 miles) behind in his first race. It is worth noting that in Rosemeyer, Müller and Meier Auto-Union had successfully enrolled ex-motor-cycling experts.

From a technical point of view the race was interesting in that both Auto-Union and Mercedes-Benz were employing two-stage superchargers, and the enormous margin of superiority held by these cars over their rivals can best be indicated by stating that in a fifty-lap race the winner finished six laps ahead of a 3-litre supercharged Alfa Romeo, and a 4½-litre unsupercharged Delahaye.

The fact that Auto-Unions had lost the Eifel Race to Mercedes-Benz by less than half a mile in a race of 142 miles augured an intense struggle for the German Grand Prix to be run over double the distance on the same course. Lang reaffirmed the speed of his car and his own personal driving skill by taking a Mercedes-Benz round in practice at 87.5 m.p.h. Nuvolari's car was in trouble prior to the race, and the best Auto-Union time was, in consequence, put up by Müller, who averaged 84.7 m.p.h. These speeds were achieved in dry, warm, weather, but on the day of the race a rapid change lowered the temperature, played havoc with carburation, made the course intensely slippery, and turned what should have been an epic struggle into something akin to a farce. Lang and Brauchitsch were in constant trouble with wet mixture which

fouled the plugs, the car which was to be driven by Seaman was a non-starter, and it was left, therefore, to Caracciola, to maintain his Company's reputation, which he did by driving steadily if somewhat slowly. He reached first position on the sixth lap and, except for the inevitable drop in position following a pit stop, did not lose it. His winning speed, 75.18 m.p.h., and best lap of 81.65 m.p.h., were, however, but little better than the figures achieved in 1934. Auto-Union were in no better case. Nuvolari also suffered from plug troubles and ran third, until he retired three laps from the end ; Müller finished second, 58 sec. behind the leader, and Meier retired at half distance. Hasse also retired on the twelfth lap ; he was then leading due to Caracciola's pit stop. Perhaps the most remarkable aspect of a sorry spectacle was the fact that on the second lap Pietsch's Maserati was able to challenge the German cars, and eventually finished third. Three Delahayes were the only other cars to finish.

The 1939 Swiss Grand Prix was the last major race of the year and to all intents and purposes the last race in which these cars appeared before a European public. Mercedes-Benz gave their fourth car to a new cadet driver, H. Brendel, but owing to an injury in the Swedish Motor Cycle Grand Prix, Meier was replaced in the Auto-Union team by the more experienced Hasse. It may seem almost redundant to record that once again it was Lang who put up the best practice time with a speed of 106.23 m.p.h., Stuck being the fastest Auto-Union man with an average of 103.3 m.p.h., with Dreyfus (now using a Maserati) achieving 96.5 m.p.h., and Farina on an Alfa Romeo 99.4 m.p.h. The last named figure was particularly remarkable as it was achieved with a new 1½-litre car (Type 158) which, although out-classed in capacity, was run in competition with the full Grand Prix types.

The day's racing consisted of two heats, one confined to 1½-litre cars, the other for full Grand Prix cars, with a final for the twenty-six fastest cars. In the smaller car race Farina won easily at an average speed of 96.4 m.p.h. In the heat for Grand Prix cars only Nuvolari was able to challenge the three regular Mercedes-Benz drivers and he was third at half distance with von Brauchitsch just behind him. The latter then put on speed and passed Nuvolari, whilst Caracciola, running second, made a supreme effort to catch Lang, and failed to do so by a mere 4.8 sec. after making the fastest lap of the day at 104.23 m.p.h. In the final Farina, on the phenomenal Alfa Romeo Type 158, made a valiant and by no means unsuccessful effort to keep up with the larger cars. Averaging 97.5 m.p.h. he was headed only by Lang for the first seven laps. Caracciola then took the matter in hand and started closing up on the leader at the rate of a second a lap, but for the second time he slightly misjudged his timing and finished second, 3.1 sec. in arrear. In the last half of the race the other larger cars also swept by Farina so that von Brauchitsch ran third, with Auto-Union fourth and fifth, and the little Alfa sixth.

Alfa Romeo had developed this smaller car to run in a number of events in which, to avoid a certain German victory, a 1.5-litre limit on engine capacity had taken the place of the International Formula.

In this way the Coppa Acerbo and Coppa Ciano, for example, disappeared from the 1939 international Grand Prix calendar, but one new event appeared on the list- the Yugoslav Grand Prix. On the 3rd September, 1939, three Mercedes-Benz and two Auto-Unions were on the starting line of a twisty course through the streets of Belgrade. This was at 5 p.m., six hours after drivers and the spectators knew that a state of war existed between Germany on the one hand and Great Britain and Poland on the

other. Brauchitsch, who had frequently been unlucky, was determined to win what everyone must have realised was to be the last Grand Prix for many months ; perhaps, as it was to prove, for many years.

He got into the lead from the start and although Lang remained very closely behind he could not pass. Additionally, on the seventh lap a stone from the rear wheel of the leading car was thrown up, breaking Lang's goggles, so that, temporarily blinded, he ran off the road. He was able to continue but came round to his pit and announced that he would retire. Brauchitsch, determined to put the matter beyond doubt, cut his times down until on the fifteenth lap he averaged 83.9 m.p.h. and led the Auto-Unions of Müller and Nuvolari by 13.8 and 14.2 sec. respectively. On the sixteenth lap his speed proved his undoing. On a right-hand turn and a 1 in 7 gradient his car swung broadside across the road and only his large lead gave sufficient time to reverse and clear the track for the two Auto-Unions who came past bonnet to tail. Nuvolari showed his subtle driving methods by slowing a little so making it awkward for Brauchitsch to pass him and allowed Müller to go well out into the lead. The latter, however, was forced to stop for tyres and Nuvolari, with the way clear, now equalled Brauchitsch's lap record and was never again to lose first place. Thus, with the victory of an Italian driving a German car in a Balkan country, Grand Prix racing, which had previously been interrupted by a five-year war, was brought to a close. Seven years, in which Germany went down in defeat and ruin, elapsed before racing was resumed before European crowds eager as ever to enjoy the grand spectacle.

CHAPTER FIFTEEN

Out of Bounds

THE main story set out in the preceding chapters has been deliberately confined to real road racing carried on within the limits of the international Grand Prix formulae in force at the time. In order to complete the picture it is desirable to deal with certain other aspects such as the Voiturette races held between 1909 and 1913 and some of the non-formula events held over exceptionally fast circuits in the decade immediately preceding the Second World War. The speeds recorded in these last-named give a distorted picture of the progress and have been excluded from the general calculations which have been made, but as the winning car was in many cases eligible to run under the current Grand Prix formulae and so complete the historic record, the facts, in brief, will now be set out.

The semi-road event was held on the Mellaha circuit in North Africa for the Tripoli Grand Prix. This particular course was established in 1933 and it should be noted that earlier Tripoli Grands Prix were run on an entirely different circuit at much lower average speeds. The 1933 event was notable for the fact that an Englishman, Sir Henry Birkin, driving a 2.8-litre Maserati, held the lead for the first four laps and at half distance was in second position only 10 sec. behind Nuvolari who was handling one of the bored-out 2.6-litre Monza type Alfa Romeos. Unfortunately, Birkin's pit was very poorly organised and his refuelling stop dropped him back to third position from which he was unable to recover. The last half of the race was in consequence a struggle between Nuvolari and Varzi, who was driving a 2.3-litre Type 51 Bugatti. At twenty laps (with ten still to go) the Alfa Romeo was in the lead, but on the twenty-fifth Varzi passed first by a margin of 20 sec. The cars then ran neck and neck, so that on the last lap Varzi won by barely a length, with one-tenth of a second in hand over his rival. This was the last race for one of Britain's finest drivers, for Sir Henry contracted a burn which turned septic and he died within a few weeks of the race being run.

The following year saw the appearance of the 2.9-litre Monoposto Type B Alfa Romeos, against which were ranged two of the new 2.8-litre Bugattis, a team of 2.9~litre Maseratis, a pair of U.S.A.-entered Miller four-wheel drive cars, and (taking advantage of this being a non-formula event) two of the sixteen-cylinder Maseratis, one with 4-and the other with 5-litre engine capacity. Only Taruffi on the last named, with a lap speed of 123 m.p.h., was able effectively to oppose Alfa Romeo, but although second on the fifth lap he later ran off the road. Wimille was able to make a fair show for Bugatti, but he retired on the twenty-fifth lap when running in fourth position and his team mate, Dreyfus, finished sixth at 107.62 m.p.h., with a lap at 116 m.p.h. The two U.S.A. cars could only manage seventh and eighth place at an overall average of little better than 104 m.p.h., so the official Alfa Romeo team annexed all first three positions. They all averaged over 115 m.p.h., and lapped at over 124 m.p.h.

Owing to this race being held in the very early part of the year none of the German cars built to the 750 Kg. formula competed in 1934, but both Auto-Union and Mercedes-Benz appeared on the scene in 1935, the former with two and the latter with three entries. Alfa Romeo opposed them by two extremely interesting double-engined cars, one of 5.8 litres and the other of 6.3 litres capacity, driven by Chiron

and Nuvolari respectively. In effect these cars used Type P.3 engines, one being mounted in the tail behind the driver and both being connected to the rear wheels. 510 and 540 b.h.p. respectively was claimed from these pairs of engines, which showed the cars a surplus of some 100 b.h.p. compared to the contemporary German models. Unfortunately, despite using 5.5 x 20 in. rear tyres the power available was too much for the existing state of tyre design and Nuvolari had to change thirteen wheels during the event. Even with this handicap he averaged 116.56 m.p.h., but this gave him no higher than fourth position.

Caracciola won on a Mercedes-Benz at an average of 123.03 m.p.h., and showed his mastery of the course by making the fastest circuit at nearly 137.81 m.p.h. only two laps from the end. Stuck on an Auto-Union achieved the same speed within the second place of decimals, but retired at half distance when in the lead. Varzi then took over the Auto-Union challenge and led the race until four laps from the end, when a pit stop put him back into the second position, in which he eventually finished. A Mercedes-Benz, driven by Fagioli, was third, so that the twelve months old German cars had a complete triumph.

This they repeated in the following year, when Varzi secured his third win on this circuit, again driving for Auto-Union. From half distance onwards he and his team-mate Stuck alternated between first and second places, and with four laps to go Varzi put in a lap at an average of 136.5 m.p.h., which gave him a lead of 15 sec. on Stuck, contrary to team orders. The latter opened up and they commenced the last lap with only a few yards separating them, but at this point Varzi raised the lap record to 141.3 m.p.h., which brought him over the line a quarter of a mile ahead of his team leader. It should be recorded that Mercedes could do no better than 136.42 m.p.h. for a lap (i.e. slower than their best 1935 speed), and although Caracciola improved slightly on the winning average of the previous year by putting up 126.08 m.p.h., this gave him only third place.

Alfa Romeo ran two twelve-cylinder 4-litre cars, but these were outpaced and in addition had serious tyre trouble. The winner stopped three times and took 2 min. 4.2 sec. to change three tyres, but Brivio (who had the fastest Alfa Romeo) finished only seventh, and although he lapped at 134.79 m.p.h. he had five pit stops aggregating 6 min. 38.4 sec. to change ten tyres.

As recorded elsewhere Mercedes-Benz introduced an entirely new design of car for 1937 and at the same time a new young driver, Herman Lang, became a regular team driver, or *Hauptrennfahrer*. The Tripoli event of that year enabled him to show his complete mastery of high speed driving, as he ran through the entire race with only one stop for tyres and averaged 134.42 m.p.h. to win by just under 10 sec. It was, however, left to one of the old guard, Hans Stuck, to make a record lap of the circuit for Auto-Union at 142.45 m.p.h., although in practice Caracciola went even faster and made the best lap for Mercedes-Benz at 143 m.p.h. Generally speaking, the Auto-Unions had the higher speed in this event, but they lacked the excellent pit control shown by Mercedes-Benz and this coupled with loss of time in extra tyre stops was a disadvantage they could not overcome.

In 1938 some reduction in speed, following the introduction of the 3-litre supercharged cars, was inevitable and the practice times showed that only Mercedes-Benz had designed a car with a performance approximating to its larger predecessor. Lang put in a lap at 140 m.p.h., but his speed was very much faster than anything achieved

by rival makes and types. The corresponding supercharged 3-litre cars of Alfa Romeo and Maserati averaged 137.2 m.p.h. and 135.7 m.p.h. respectively, and these in turn were much faster than the unsupercharged 4½-litre Delahayes, the best of which averaged 126.5 m.p.h.

Lang repeated his 1937 victory and led almost throughout, but the Alfa Romeo driven by Farina held second and third positions between the first and fifth laps, and Count Trossi's Maserati made a brief appearance in first and second positions in the ninth and tenth laps respectively and, in addition, made the fastest lap of the day at 131.2 m.p.h. This, however, led to the breakdown of the car and to an easy victory for Mercedes-Benz, who finished in the first three positions. The two Alfa Romeos, one with twelve and the other with sixteen cylinders, both retired, allowing an eight-cylinder type to finish fourth, nearly a quarter of an hour behind the winner. In 1939 the race was confined to 1½-litre cars.

The A.V.U.S. races were instituted in 1921 over a section of twin track road leading from Wannsee, a suburb of Berlin, to Potsdam, which had been converted into a toll road for cars only.

The German Grand Prix (not a formula event) was held on this course in 1926 and it was won by a 2-litre Mercedes driven by Caracciola at an average speed of 84.15 m.p.h. This type of car lived up to its reputation of being very difficult to handle and led to a terrible crash by Rosenberger, who hit the timekeepers' box when leading, killing two officials and severely injuring himself. Due to wet weather and slippery surface this was, taken all round, a very dangerous race, and even the skilled veteran Chassagne, driving one of the well proved, four-cylinder 1½-litre Talbots, overturned, as did his team mate, Urban-Emmerich, who was actually in the lead when he crashed.

The first A.V.U.S. Grand Prix was instituted in 1931, Caracciola again being the winner, the car now being a Mercedes-Benz of the well-known SSKL type.

In 1932 a large entry was received, consisting of nine Bugattis, two backed by the works, three Maseratis, two Mercedes-Benz, a Monza Type Alfa Romeo, and a 4-litre V.12 Sunbeam. One of the Maseratis was the celebrated 5-litre sixteen-cylinder model which put the lap record at over 130 m.p.h., only to develop engine trouble at the sixth lap by which time the field had been reduced to ten cars. Caracciola held the lead for some time on the solitary Monza type, but he was passed on the last lap by von Brauchitsch driving a 7-litre SSK Mercedes-Benz with a cumbersome looking, but quite effective, streamlined single-seater body. Brauchitsch won by a mere 4 sec. in 1½ hours racing, with a privately owned Bugatti third.

The race was now well established on the International Calendar and in 1933 entries were received from Ferrari, running three of the modified Monza Alfa Romeo cars, and Bugatti, who was represented by three of his 4.9-litre Type 54 models and three Type 51's. Brauchitsch appeared again and this year was the sole Mercedes-Benz representative, but he had to make five stops for tyres and was only able to gain sixth position at an average of 109.92 m.p.h. Two of the Ferrari Alfas dead-heated in third place at 120.66 m.p.h., but neither could approach the speed of the big Bugattis. The car driven by Count Czaykowski raised the lap record to 137.77 m.p.h. and led until the thirteenth lap, but Varzi on the sister car got past on the fourteenth lap and won on the next circuit by a margin of one-fifth of a second at an average of 128.48 m.p.h.

The 1934 event, which marked the first appearance of the German 750 Kg, formula cars, has been referred to in Chapter Ten. It was notable for a new lap record by Momberger on an Auto-Union and also for the defeat of the German cars by the 3.2-litre Alfa Romeo driven by Moll. This win was reinforced by another Alfa Romeo taking second position.

In 1935, however, the German cars were really running properly and they put everybody else completely out of the picture. In practice Hans Stuck put in a lap for Auto-Union at 161.88 m.p.h., Caracciola lapping at 150 m.p.h. for Mercedes-Benz. Nuvolari achieved 150.5 m.p.h. on a twin-engined Alfa Romeo, but one of the more normal 3.2-litre eight-cylinder cars could do no better than 132.6 m.p.h.

The day's racing of May 26th consisted of two heats and a final. Preliminary events were won by Stuck and Caracciola at 155.53 and 147.87 m.p.h. respectively, the big Alfa Romeos suffering from their usual chronic tyre trouble. One of them, driven by Chiron, was able, nevertheless, to qualify for the final, as did the P.3 model driven by Dreyfus. Two Auto-Unions and four Mercedes-Benz completed the line-up of eight starters in the ten-lap final amounting to 122 miles. At half distance two of the Mercedes-Benz had retired (including Caracciola's), and the third driven by von Brauchitsch was poorly placed due to tyre stops. Stuck also suffered from this malaise and had to call at the pits twice, as did his team-mate Varzi. It thus came about that Fagioli on a Mercedes-Benz and Chiron on an Alfa Romeo took first and second positions by virtue of having non-stop runs.

No race was held in 1936, but in 1937 it was run over a substantially modified course. The loop at the Potsdam end, with a 1 in 9 banking, was left unchanged but at the Berlin end a new corner was laid out in a 300 ft. radius with a banking of 43 degrees and this enabled the cars to continue on this section at full speed.

Taking advantage of the possibilities thus presented of sustained maxima both the German constructors entered specially designed cars and in the face of this competition no other works' entries were received. Auto-Unions made no great changes to their Grand Prix chassis but two cars driven by Rosemeyer and Fagioli were fitted with all enveloping aerodynamic bodies, another pair being standard Grand Prix models. Mercedes-Benz had greater variety. They had five cars entered, three of them driven by Caracciola, Brauchitsch and Lang, with all enveloping aerodynamic bodies and two in the hands of Seaman and Zehender of Grand Prix form. There was, however, a further variation in that the cars driven by Brauchitsch and Zehender, that is one of each type, were fitted with a 5.57-litre V.12 engine (82 x 88 mm.) giving 679 h.p., that is to say 100 b.h.p. more than the straight-eight engine was developing at this time of the year.

The fastest lap in practice was made by Fagioli on an aerodynamic Auto-Union at 174 m.p.h., and owing to Zehender's engine developing mechanical trouble before the race entries were reduced to eight cars, four from each factory.

Starting positions were determined by speeds for a standing lap over the 12 miles circuit and it is interesting to analyse the times as an indication of the effect of engine type and body form. The streamlined Auto-Unions averaged 171.6 m.p.h. and the best Grand Prix type of the same make at 165 m.p.h. The twelve-cylinder 679 h.p. Mercedes-Benz with streamlined body work averaged 170.2 m.p.h., the eight-cylinder 568 h.p.

fully streamlined car 165 m.p.h., and the same engine with the normal Grand Prix body 159.5 m.p.h.

In the first heat Auto-Unions were represented by Rosemeyer and Delius, and Mercedes-Benz by Caracciola and Seaman, the first named in each team with streamlined and the second with G.P. models, and the drivers kept their speed well down. After making the fastest lap of the day at 171.6m.p.h., Rosemeyer had trouble with his oiling system and this let Caracciola win at 155.59 m.p.h. In the second heat Brauchitsch and Lang drove two streamlined Mercedes-Benz, Fagioli drove a similar type of Auto-Union and Hasse a Grand Prix Auto-Union. Fagioli broke up his engine when in the lead, giving first and second places to Brauchitsch and Lang, the winning speed being 160.37 m.p.h.

In the final the aerodynamic Auto-Union of Rosemeyer lost oil pressure and Von Delius and Hasse with ordinary Grand Prix models were unable to make much impression on Lang, who drove carefully, had no tyre stops, and averaged 162.5 m.p.h. Caracciola set the pace from the start but he had to retire on the fourth lap with rear axle trouble after averaging 165 m.p.h. for the first three laps.

The speeds achieved in this event are by far the highest ever recorded in any race, but the type of cars used showed a very marked divergence from practical road racing lines, quite apart from any question of technical compliance with the formula. They were perhaps the inspiration of an Auto-Union of a similar type which was entered for the French Grand Prix at Rheims the following year, but on a road circuit the stability problems of a streamlined car proved insuperable. The car left the course when practising and was seen no more in Grand Prix racing.

As with the A.V.U.S. series of races so with the Targa Florio, there was no restriction on the type or size of car entered nor, moreover, was there any limit to the number of mechanics who could help with repairs or refuelling. Whereas, however, the German track exaggerates the possible average speed of any given car in relation to a normal Grand Prix circuit, the Sicilian event depreciates it to an even greater extent.

The event was first held for a Trophy put up by Count Florio in 1906 and at this time the speed of the winner, Cagno, on an Itala of 29.18 m.p.h. was about half that of the overall average returned by the winner of the French Grand Prix. This was accounted for by the rough mountain roads which abounded in hairpin corners, and even when André Boillot was driving the 2½-litre Peugeot to the utmost in 1919 (vide Chapter VI) his average speed was little more than 34 m.p.h. In 1920 the race was won by Count Masetti driving one of the 1914 Lyon Grand Prix Fiat cars and was notable for the first appearance of a supercharged car in European road racing, in the form of a Mercedes which gained second place in the hands of Max Sailer. In the following year the Count Masetti repeated his win, this time on a 1914 Lyon Grand Prix Mercedes and this marque was the first to put the average speed over 40 m.p.h., when the event was won by Christian Werner driving a four-cylinder 2-litre supercharged car in 1924.

The five races held between 1925 and 1929 were all won by the Type 35 Bugatti, racing unsupercharged in the first year, and supercharged thereafter, and although Peugeots were second and third with sleeve valve engines in 1925 Maserati took third place in 1927 and Alfa Romeo second in 1929. With these exceptions Bugatti took 1st and 2nd or 1 st, 2nd and 3rd positions as the case may be, and with the collapse of Grand

Prix racing in 1926 and 1927 the Targa Florio became the most important pure racing event on the calendar. To keep the history of racing in its proper perspective the overwhelming success of Bugatti in Sicily in these years must therefore be set against their comparative inability to shine against the absolutely faster Talbots and Delages in the 1½-litre Formula events.

The races run between 1928 and 1933 have been referred to in Chapters IX and X and, unfortunately, with the introduction of the 750 kg. Formula, the race ceased to have any technical or " political " significance and was indeed run for the last time over the traditional circuit in 1935. Nevertheless, in order to complete the statistical evidence of road racing the results from 1919 to 1927 and in 1934 and 1935 are set out at the end of this Chapter.

RACING STATISTICS FOR TARGA FLORIO 1920-27 AND 1934-35

Date	*Event*	*Circuit*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Best Lap m.p.h.*
!4/10/20	Targa Florio	Madonie	G. Meregalli	Nazzaro	35.99	—
29/5/20	Targa Florio	Madonie	Count Masetti	Fiat	36.19	37.5 (Sailer, Mercedes)
21/4/22	Targa Florio	Madonie	Count Masetti	Mercedes	39.2	41.3
15/4/23	Targa Florio	Madonie	U. Sivocci	Alfa Romeo	36.69	40.8
27/4/24	Targa Florio	Madonie	C. Werner	Mercedes	41.02	42.4
3/5/25	Targa Florio	Madonie	M. Costantini	Bugatti	44.5	45.1
25/4/26	Targa Florio	Madonie	M. Costantini	Bugatti	45.68	46.8
24/4/27	Targa Florio	Madonie	E. Materassi	Bugatti	44.61	47.2
24/4/27	Targa Florio	Madonie	F. Minoia	Bugatti	—	46.78
20/5/34	Targa Florio	Madonie	A. Varzi	Alfa Romeo	43	—
20/5/34	Targa Florio	Madonie	P. Ghersi	Alfa Romeo	—	45.76
28/4/35	Targa Florio	Madonie	A. Brivio	Alfa Romeo	49.18	49.72

RACING STATISTICS TRIPOLI, 1933-38

Date	*Event*	*Course*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Best Lap m.p.h.*
7/5/33	Tripoli G.P.	Mellaha	A. Varzi	Bugatti	104.7	110*
6/5/34	Tripoli G.P.	Mellaha	A. Varzi	Alfa Romeo	115.67	—
6/5/34	„	„	L. Chiron	Alfa Romeo	—	124.48*
12/5/35	Tripoli G.P.	Mellaha	R. Caracciola	Mercedes-Benz	123.03	136.81*
10/5/36	Tripoli G.P.	Mellaha	A. Varzi	Auto-Union	129.01	141.29*
9/5/37	Tripoli G.P.	Mellaha	H. Lang	Mercedes-Benz	134.42	—
9/5/37	„	„	H. Stuck	Auto-Union	—	142.44*
15/5/38	Tripoli G.P.	Mellaha	H. Lang	Mercedes-Benz	127.4	139.7 (P)
15/5/38	„	„	Count Trossi	Maserati	—	131.2

* Record

RACING STATISTICS A.V.U.S., 1931-38

Date	*Event*	*Circuit*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Best Lap m.p.h.*
2/8/31	Avusrennen	A.V.U.S.	R. Caracciola	Mercedes-Benz	115.39	121.65*
22/5/32	Avusrennen	A.V.U.S.	M. von Brauchitsch	Mercedes-Benz	120.07	—
22/5/32	Avusrennen	A.V.U.S.	R. Dreyfus	Maserati	—	130.39*
21/5/33	Avusrennen	A.V.U.S.	A. Varzi	Bugatti	128.48	---
21/5/33	Avusrennen	A.V.U.S.	Count Czaykowski	Bugatti	—	137.77*
27/5/34	Avusrennen	A.V.U.S.	G. Moll	Alfa Romeo	127.57	—
27/5/34	Avusrennen	A.V.U.S.	A. Momberger	Auto-Union	—	140.33*
26/5/35	Avusrennen	A.V.U.S.	L. Fagioli	Mercedes-Benz	148.83	---
26/5/35	Avusrennen	A.V.U.S.	H. Stuck	Auto-Union	—	161.88*
1936	Not Run					
30/5/37	Avusrennen	A.V.U.S.	H. Lang	Mercedes-Benz	162.61	—
30/5/37	Avusrennen	A.V.U.S.	B. Rosemeyer	Auto-Union	—	172.75*

* Record

Part Two

EXAMPLES OF THE GRAND PRIX CAR

Technical Descriptions

" How small is the power of word to convey clear notions of visible things, and on the contrary how well fitted for this task is the craft of the limner."

LEONARDO DA VINCI.

"The test of truth in matters of practice is to be found in the results obtained, for it is only in them that supreme authority resides."

ARISTOTLE.

EXAMPLE No. ONE

The 1908 Itala

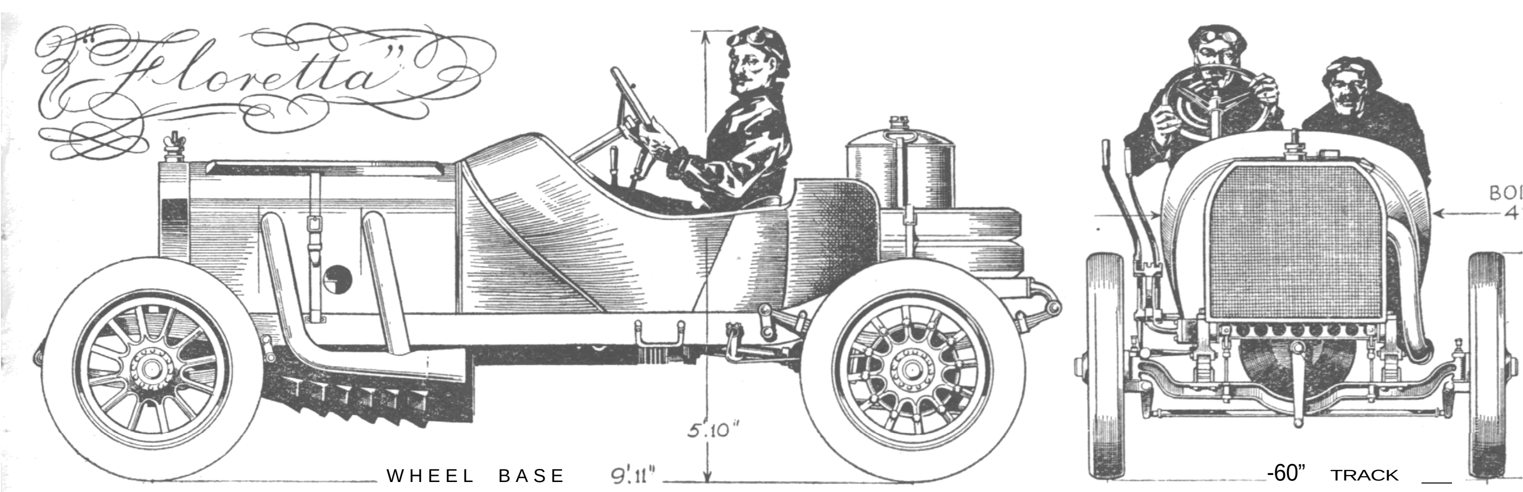
THE regulations for the 1908 races proposed by the Automobile Club de France stipulated that the minimum weight should be not less than 1,150 Kg. (approximately 22.6 cwt.), and that the bore should not exceed 155 mm. for four-cylinder cars, the equivalent of a piston area of 117 sq. ins.

The car constructed by the Itala Company for this race can be considered highly typical of design practice at this time. It embraced a live rear axle, a feature which was perhaps something of an advance, but, on the other hand, retained side exhaust and overhead inlet valves and low tension ignition at a period when overhead valve engines with high tension ignition were by no means unknown.

A team of three cars was entered, and although the highest position gained was eleventh at an average of 57.8 m.p.h., it is worth noting that on the first lap of 48 miles an Itala was only 57 secs. behind the eventual winner, Lautenschlager on a Mercedes.

In 1940 the same car was timed at Brooklands to cover a flying quarter mile at 85 m.p.h. and a standing quarter mile in 20 secs. The car was not in the best of tune when these last-mentioned figures were achieved, and it is fair to assume that in original condition the speed of the car would lie between 95 and 100 m.p.h., the latter representing a probable flat-out speed.

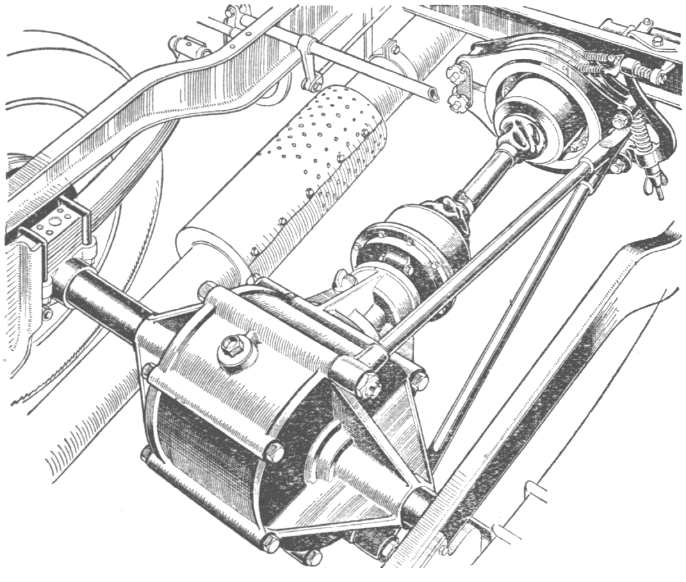
The scale and perspective drawings both indicate the comparatively large size of the car, but it is worth emphasising that there was very little waste space. It is indeed notable that the bonnet fits so closely around the engine that the overhead valve gear projects above the level of the radiator and had to be covered by a protuberant cowling. The height of the driver was also determined largely by the diameter of the wheels and



the method of mounting both front and rear springs above the axle level. The front axle was of normal H section cranked down to give clearance beneath the nose of the engine. Quite straight-forward semi-elliptic springs were attached to straight channel section frame. The rear springs were also of this type and were shackled at the forward end only. The rear end of the frame was splayed slightly outwards and upwards, and gave clearance for the vertical movement of the live rear axle.

Itala were amongst the first to depart from chain drive and on this car the bevel and differential gears were contained in a large, light-alloy casting to which deeply ribbed flanged members were bolted, the latter having steel axle tubes shrunk in them. The drive was taken through the springs but a triangulated arm ran forward to a pivot mounted behind the gearbox so as to relieve the spring leaves from torque.

The open propeller shaft was short and included two Hooke-type universal joints made entirely of case-hardened steel and assembled with a circumferential ring made in two halves bolted together. The foot brake was connected to two external shoes contracting upon a drum on the nose of the propeller shaft, the hand brake expanding shoes in rear wheel drums.



The " live " rear axle was an innovation

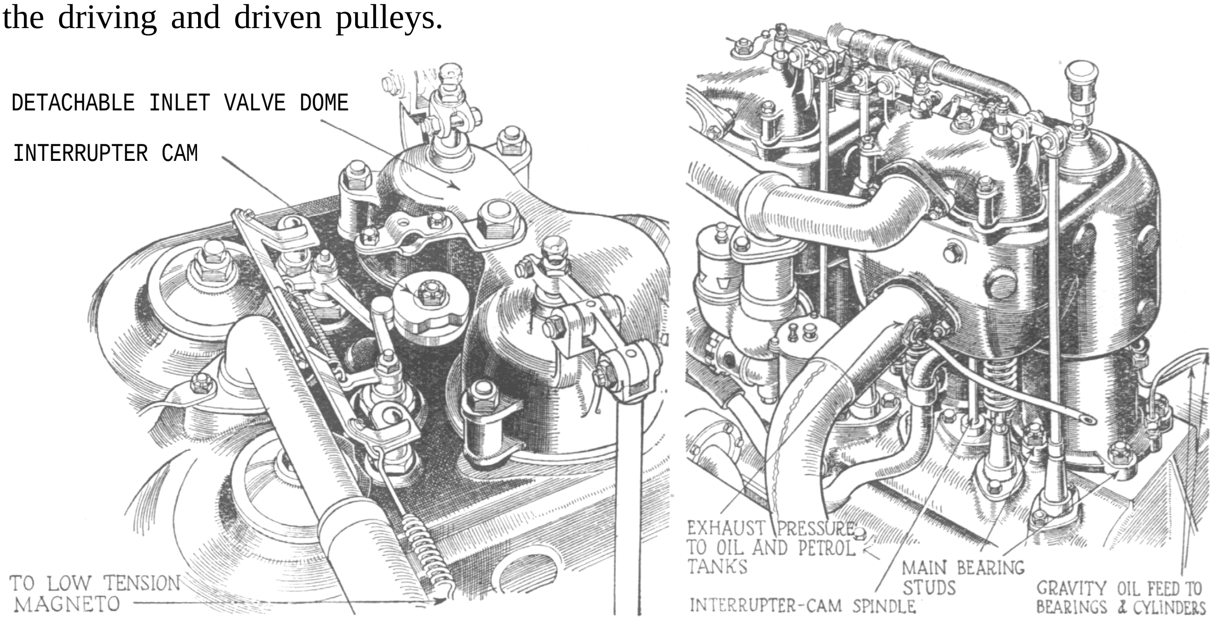
The transmission gears were contained in a light alloy housing mounted on the midpoint of the frame and although all reflect the comparatively low engine speed it will be seen that the actual gaps between them are comparatively wide. Power was transmitted between the engine and the box by clutch containing 72 steel plates each approximately 10½ in. diameter.

The design of the power unit was, of course, strongly influenced by the regulations of the race. The designer chose the maximum permitted bore and cautiously approached the problem of raising the piston speed above the 1,500 r.p.m., which was the then existing standard. Given the opportunities of unlimited stroke, he decided to fix the figure at 160mm., which permitted a maximum engine speed of 1,800 r.p.m. with a piston speed of 1,700 f.p.m. At this speed the car was theoretically capable of 113 m.p.h. so there was a reasonable balance between the factors of b.h.p., r.p.m. and reliability.

The cylinders were formed in pairs from iron castings, the water jacket extending about one-third of the way down the bore. The exhaust valves were situated in laterally located pockets at the near side of the engine, the inlet valves being mounted above them in detachable cages. The exhaust valves, therefore, were operated directly from a side mounted camshaft and the inlet valves through push rods and rockers, the latter mounted in the plane of the crankshaft. The camshaft also drove vertical shafts driving a cam on the top of the cylinder head which impinged on short spring-loaded rockers operating the wipe contacts of the low tension ignition system inside the combustion space. Skew gears were used for driving purposes and enabled the timing to be advanced or retarded by moving the camshaft endwise.

Slightly domed cast-iron pistons gave a compression ratio of approximately 4½ : 1 and the long connecting rods have offset big ends with white metal bronze shells. The crankshaft ran in a similar type of bearing and was approximately 55 mm. diameter, and innocent of counterbalancing.

The three main bearings were bolted to the crank case through intermediate distance pieces and extensions of the bolts were used for turning cylinder blocks on the face of the crank case. A somewhat elaborate lubrication system was used in which an external reserve oil tank, maintained under pressure by exhaust, fed, as required, to a container mounted on the driver's side of the scuttle. This container had a sight level glass facing the driver and contained eight double reciprocating plunger pumps worked by a transverse rocker and driven by a spring-built drive from an external pulley on the end of the camshaft. Each double pump was connected to a separate oil pipe, three connecting directly to the main bearings and four to the cylinder walls with holes for attachment alternatively to the thrust face of the pistons or at 90º thereto. The remaining pump was joined to 12 small-bore open-ended pipes which dropped oil over appropriate parts of the valve gear. It must be emphasised that there was no return of oil from the crank case, the delivery being controlled by the relative size of the driving and driven pulleys.



Engine details

Manifolding consisted, on the exhaust side, of two pipes passing through the bonnet side and connecting to the centre of each pair of cylinders. The inlet manifold was Y shaped, each branch feeding a pair of inlet valves and receiving mixture from a vertical carburetter of Itala design. The diameter of the pipe was 60 mm. and at maximum engine speed the gas velocity was therefore approximately 125 ft. per second. A large water pump was driven from the front of the engine, distributing the coolant through another Y-shaped pipe directly on to the seat of the exhaust valves, thus forming a somewhat striking anticipation of the modern principle of direct water flow.

The 1908 Grand Prix Itala was somewhat overweight and under-powered by comparison with the best designs of the time and for this reason had no great success in Grand Prix racing. It has, however, in later years proved to be an outstandingly reliable design, two cars participating in racing at Brooklands until 1914, one in 1910 averaging 97.5 m.p.h. for 194 miles and lapping at 101.8 m.p.h. This car survived and continues in competition use to-day.

Acknowledgments. -Thanks are due to Messrs. R. Wil-de-Goose, C. Clutton and Dr. G. A. Ewen for assistance in obtaining data on this car,

DETAILS OF CAR

MAKE.-Itala
TYPE.-G.P.
YEAR OF CONSTRUCTION.-1908
YEAR RACED.-1908 by constructors.
DESIGNER.-
WHEELBASE.-9ft. 11 in.
TRACK FRONT.-5ft.
TRACK REAR.--5ft.
HEIGHT TO SCUTTLE.-56in.
HEIGHT TO DRIVER'S HEAD.-67in.
FRONTAL AREA.-18.5 sq. ft.
UNLADEN WEIGHT.-27.8 Cwt.
ALL-UP STARTING LINE WEIGHT.-32.3 cwt.
MAXIMUM SPEED.-100 m.p.h.
SPEED ON INDIRECT GEARS.-77 m.p.h. in Third
„ „ „ „ 55 m.p.h. on Second
34 m.p.h. on First
H.P. PER SQ. FT.-5.4
H.P. PER TON UNLADEN.-72
H.P. PER TON ALL UP.-62
BORE.-155 mm.
STROKE.-160 mm.
S.B. RATIO.-1.03
NO. OF CYLINDERS.-4
CAPACITY.-12,000 c.c.
PISTON AREA.-117 sq. in.
B.H.P.-100 at 1,600 r.p.m.
H.P./SQ. IN-0.85
B.M.E.P.-68
PISTON SPEED FT./MIN.-1,700
CYLINDER HEAD.-Integral C.I.
VALVES NO.-2 per cylinder
VALVES ANGLE.-opposed
VALVES AREA INLET.-41 sq. in.
VALVES AREA EXHAUST.-48.5
CYLINDER BLOCK.-Cast-iron in Pairs
CARBURETTER.-Itala vertical
FUEL.-Petrol
SUPERCHARGER.-Nil
MANIFOLD PRESSURE.-Atm.
IGNITION.-one low tension magneto
PLUGS. NO.-Four low tension contact breakers
PLUGS LOCATION.-Offset in head
CRANKCASE.-Two-piece light alloy
CRANKSHAFT.-One-piece no counter balancing
MAIN BEARING NO.-3 fixed to cylinder castings
MAIN BEARING TYPE.-White metal
BIG END TYPE.-White metal
LUBRICATION.-Gravity and splash
CAMSHAFT NO.-1
CAMSHAFT LOCATION.-Inside of crankcase
CAMSHAFT DRIVE.-Gears
CAMSHAFT DRIVE LOCATION.-Front of crank
CLUTCH.-Multi-plate
GEARBOX LOCATION.-Separate from engine.
GEAR RATIOS.-1.65, 2.4, 3.4, 5.4
TRANSMISSION.-open propeller shaft to live rear axle with triangulated torque arm.
FRAME.-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBER TYPE.-Friction
BRAKE SYSTEM.-Mechanical pedal to transmission; hand to rear wheels
BRAKE DRUM DIAMETER.-Pedal 6¼ in.
Rear 16¼ in.
BROKE DRUM WIDTH.-Pedal 3 in.
Rear 3 in.
SQ. IN, PER TON LADEN.-130
STEERING-Worm and wheel. 1 turn lock to lock
WHEELS TYPE.-Fixed wood Dunlop detachable rims
TYRES.-Front and Rear : Dunlop 895 x 135

RACING RECORD OF THE 1908 ITALA

Date	*Event*	*Course*	*Speed*	*Lap Speed*
7/7/08	French G.P.	Dieppe	58.7 m.p.h. (11th)	72.5 m.p.h.

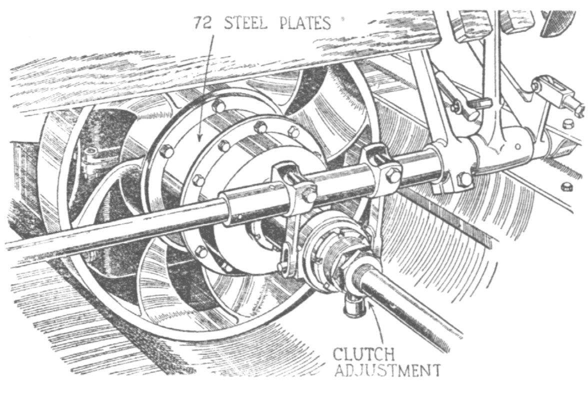
EXAMPLE No. TWO

The 1911 Fiat

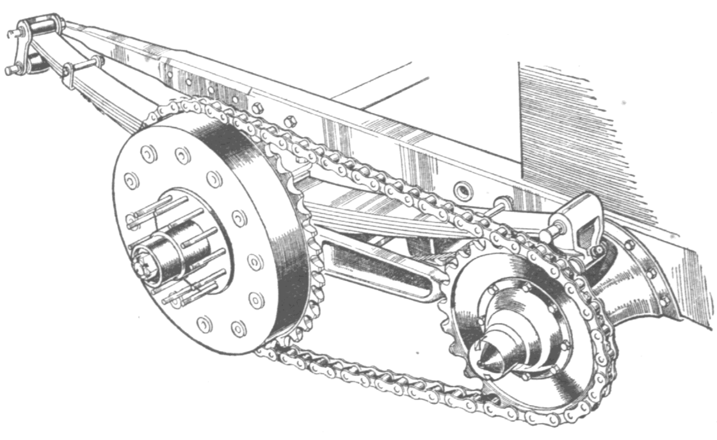
THE Fiat which won the 1911 Grand Prix de France was a catalogue model privately entered. It was a genuine racing type, designed in 1909, but raced in America during 1910 in the Savannah Grand Prize and variously known as the " Savannah G.P. Model " and the " 90 h.p. type." The manufacturers' designation is " Model S.61."

There is reason to believe that the winning car in the French event had been delivered some time previously to a Paris coach-builder in order to fit a closed body to the order of a customer. The latter, it is said, refused to take delivery and after a long delay the car was bought and raced without modification. Such a series of events readily explains the very upright driving position, square dashboard, long wheelbase, high weight and other features which one would not expect on a pure racing car. That it was nevertheless the fastest car on the course is proved by a record fourth lap at 67.75 m.p.h.

Subsequently this type of car was driven at Brooklands with a swept tail ending the two-seater body, and light alloy pistons. In this form it was capable of lapping the track in 1921 at 104.8 m.p.h. These figures are definitely superior to those which would have been obtained in 1911 as the car was then fitted with body having higher drag and running on somewhat worse fuels. It will, however, be safe to assume that in its original form the car could reach 95 m.p.h.



Clutch and flywheel details

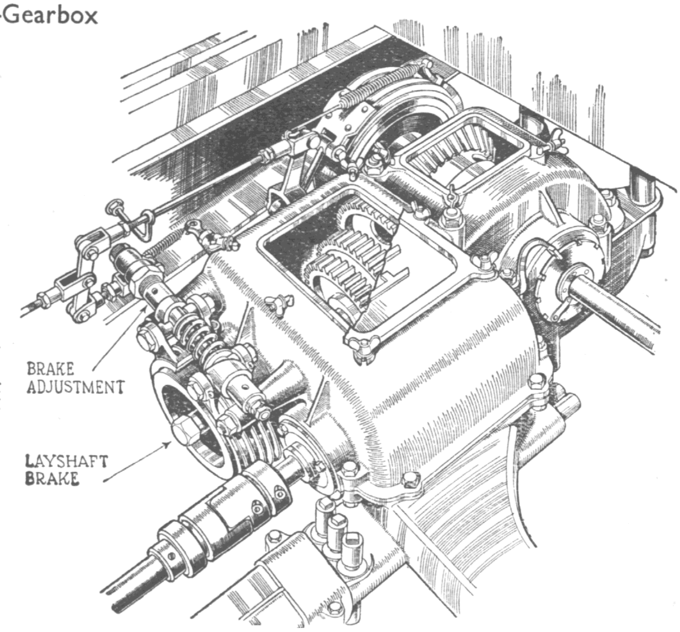


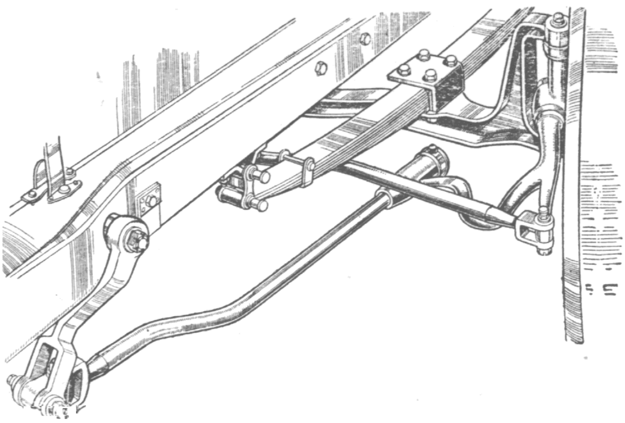
Fiat continued the use of chain final drive

The chassis design was completely in accord with the normal practice of the day, but Fiat were one of the last constructors to abandon chain drive, a system with many good points, some of which have only recently been rediscovered and revised by the more complicated layout of the De Dion type rear axle. With chain drive unsprung weight is reduced to a minimum, the springs are relieved from driving torque and transverse torque is contained within the frame so that there is no tendency for one back wheel to lift off the road when accelerating.

On the Fiat the overall gear ratio could be varied quickly by changing sprockets, and the gear reduction on the bevel drive gave a 1.5: 1 overall ratio when the sprockets were of equal size. The bevelbox was formed in one casting with the gearbox and markedly offset from the centre line, the primary and lay shafts of the box being mounted side by side and the former receiving power direct from an exposed shaft from the clutch.

Right—Gearbox





Front suspension and steering

The brake gear embodied some highly ingenious details. In addition to the normal two-shoe internal expanding brakes on the rear wheels there were two external contracting brakes on the transmission system and one of these (7 in. in diameter) was attached to an extension of the gearbox lay shaft and thus imposed reverse loading on the gear and bevel wheel teeth. The other (9 in. in diameter) was mounted on one of the fixed half shafts and therefore imposed loads only on the chains. Both brakes however, were coupled together and linked to the pedal and both were water cooled: A water tank supplied fluid through a control valve set by a trip gear on the brake pedal. When the latter was depressed a stream of water was poured onto the drum, exerting both a cooling and a cleaning effect. When the foot was removed from the pedal the trip mechanism caught up and a valve cut off the water supply,

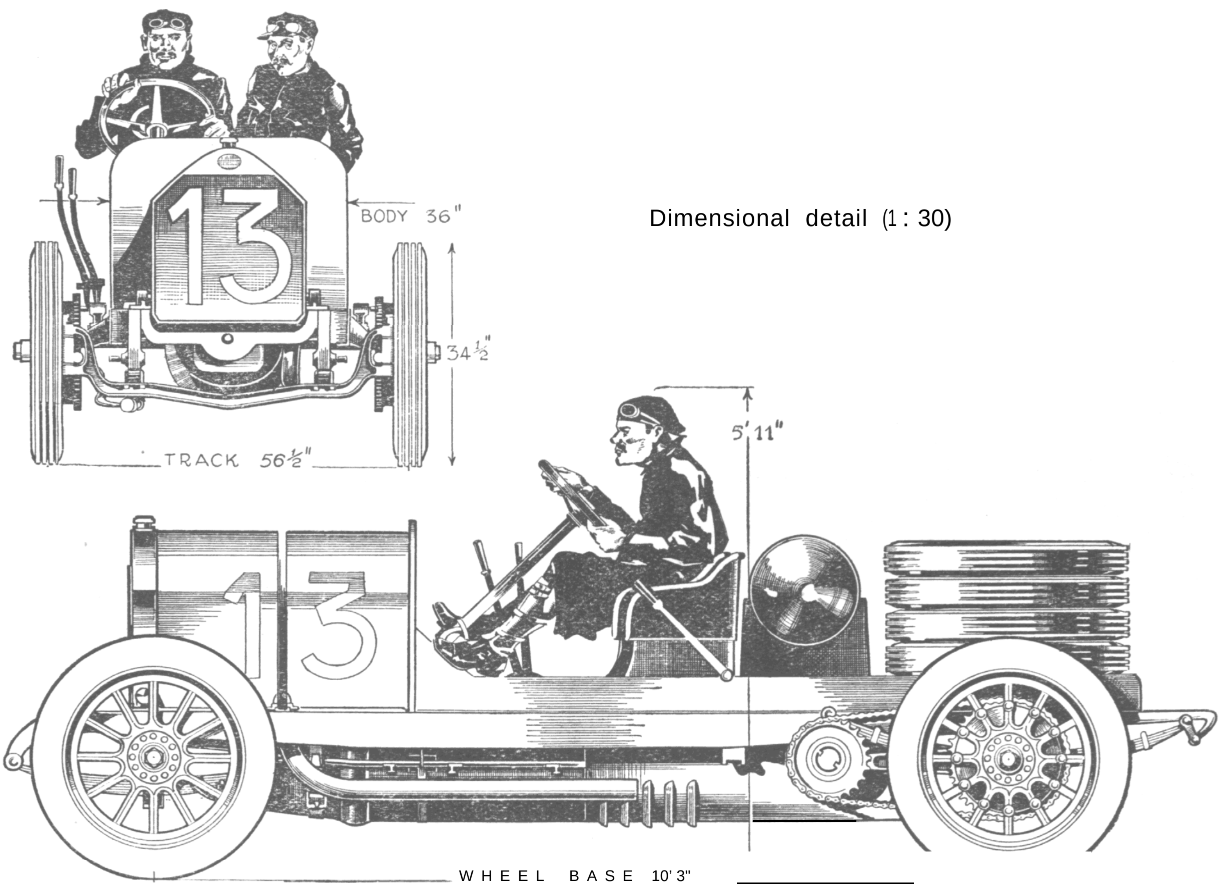
Brake and clutch pedals were mounted on a cross shaft which also carried the clutch withdrawal mechanism and adjustment. The clutch in itself consisted of seventy-two steel plates enclosed within a flywheel having a 22 in. diameter rim and vane-type spokes designed to extract hot air from the bonnet and pass it beneath the floor of the cowling beneath the frame, the latter being suitably vented to assist the egress of air.

The engine formed the principal feature of interest in this car for it anticipated many features incorporated in later cars.

The drawings show that the cylinder block was formed from two iron castings the heads being cast integral and carrying four vertical valves per bore each held (as shown in a detail sketch) in a detachable cage. They could thus be removed quickly and

the valve ground into the cage seating, the whole assembly being rendered gas-tight by pulling down on to a copper asbestos washer.

A single overhead camshaft ran along the centre line of the head, there being one inlet and one exhaust cam per cylinder. Each cam (separately machined and keyed to the shaft) engaged with a roller centrally disposed upon a bridge piece connecting to a pair of valves. The latter were mounted transversely, so that there was an inlet and an exhaust valve on each side of the head, a feature making for simplicity in the



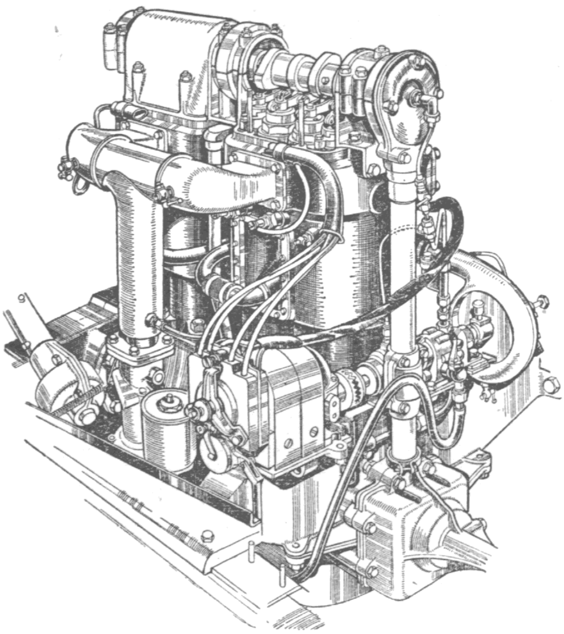
Dimensional detail (1 : 30)

valve gear and a good heat balance across the head, but involving a somewhat complicated porting system for the inlet and exhaust manifolds. These were grouped on opposite sides so that each valve had one port feeding direct from the manifold and another cored through the cylinder head.

The inlet manifolding comprised a vertical type carburetter mounted to a curved riser which ran into the vertical portion of the inlet system and then joined a straightforward T-shaped manifold. The exhaust pipe was of Y formation, designed so that the overlapping exhaust impulses exerted a mutual extractor effect.

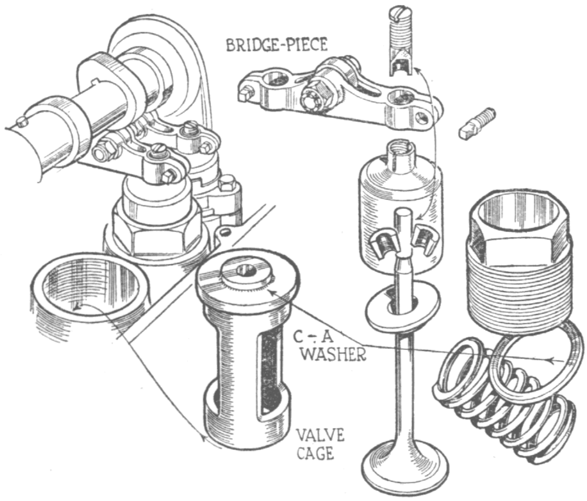
Cooling was by a large diameter water pump which delivered fluid to detachable plates on the inlet manifold side of the engine, although the pump itself was on the exhaust manifold side. It will, however, be remembered that each side of the engine contained an equal number of exhaust and inlet valves, and the circulation was designed so that a cross flow was derived by having two water offtakes at the top of the pump side of the engine.

The pump was driven by a cross shaft which also served the oil pump and magneto, the latter mounted at right angles to the crank axis and on the right-hand side of the car. This shaft was driven by skew gears from the vertical drive provided for the camshaft, which had bevel gears top and bottom. A highly interesting detail feature of this design was the magneto drive which incorporated a quick thread device so that spark timing could be varied without changing the optimum relation between magneto armature under the contact breaker. The high tension magneto (of Bosch manufacture) was fitted with a dual distributor, the engine having plugs horizontally mounted on both sides of the cylinder head. The oil pump, although of comparatively small capacity, gave 25 lb. oil pressure throughout, the engine lubrication being fully forced, including the camshaft and valve gear.



Left-Engine showing camshaft details

Below-Valve details



The cylinders were bolted to a split crankcase with four bearer arms, the crankshaft having three white metal bearings and not counterbalanced. Steel connecting rods and cast-iron pistons were features of the original design, and making comparison with the known performance of the car, one may fairly agree with the declared engine output for the race, which was 120 b.h.p.

In respect of minor details of design, drawings show that the channel frame was connected to the front and rear axles through the normal semi-elliptic springs, the rear springs being shackled at both ends and carried at the back by forged spring horns. Fixed wooden wheels with detachable rims were employed and the steering gear embodied a worm and wheel mechanism giving about 1¼ turns over the full lock. The illustrations are from a car in its long chassis form as run in the Grand Prix de France.

Acknowledgments.-A. S. Heal, Esq., owner of one of these cars, has given great assistance in obtaining details and drawings.

DETAILS OF CAR

MAKE.-Fiat
TYPE.-Model 6
YEAR OF CONSTRUCTION.-1910
YEAR RACED.-1911.
DESIGNER.-
WHEELBASE.-10 ft. 3 in.
TRACK FRONT.-4 ft. 8½ in.
TRACK REAR.-4 ft. 8½ in.
HEIGHT TO SCUTTLE.-51 in.
HEIGHT TO DRIVER'S HEAD.-71 in.
FRONTAL AREA.-18 sq. ft.
UNLADEN WEIGHT.-28 cwt.
ALL-UP STARTING LINE WEIGHT.-33 cwt.
MAXIMUM SPEED.-100 m.p.h.
SPEED ON INDIRECT GEARS.-65 m.p.h. on 3rd
,, ,, ,, ,, 45 m.p.h. on 2nd
,, 30 m.p.h. on 1st
H.P. PER SQ. FT.-6.8
H.P. PER TON UNLADEN.-85
H.P. PER TON ALL-UP.-71
BORE.-130 mm.
STROKE.-190 mm.
No. OF CYLINDERS.-4
CAPACITY.-10,008 c.c.
PISTON AREA.-83 sq. in.
B.H.P.-120 at
R.P.M.-1,650
H.P. PER SQ. IN.-1.45
B.M.E.P.-78
PISTON SPEED FT./MIN.-2,060
CYLINDER HEAD.-Integral cast-iron
VALVES No.-4
VALVE ANGLE.-Vertical in head
VALVES AREA INLET.-
VALVES AREA EXHAUST.-
CYLINDER BLOCK.-Cast-iron in pairs
FUEL.-Petrol
CARBURETTER.-Fiat vertical
SUPERCHARGER.-Nil
MANIFOLD PRESSURE.-Atm.
IGNITION.-One Bosch high tension magneto
PLUGS NO.-8
PLUGS LOCATION.-Horizontally opposed in head
CRANKCASE.-TWO-piece light alloy split on bearings
CRANKSHAFT.-One-piece no counterbalancing
MAIN BEARING No.-3
MAIN BEARING TYPE.-White metal
BIG END TYPE.-White metal
LUBRICATION.-Fully forced wet sump
CAMSHAFTS No.-1
CAMSHAFT LOCATION.-Central above cylinder head
CAMSHAFT DRIVE.-Shaft and bevel gears
CAMSHAFT DRIVE LOCATION.-Front of crank
CLUTCH.-Multi-plate
GEARBOX LOCATION.-Separate from engine
GEAR RATIOS.-1.7, 2.6, 4.05, 6.25
IGNITION.-By open propeller shaft to gear-bevel box aggregate mounted on frame. Bevels drive to cross shaft and sprockets with final chain drive to rear axle located by radius arms
FRAME.-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBER TYPE-Nil
BRAKE System.-Mechanical. Pedal to two contracting bands on transmission systems with water cooling. Hand to internal expanding shoes on rear axle.
BRAKE DRUM DIAMETER.-Pedal 9 in. and 7 in.
Hand 16½ in.
BRAKE DRUM WIDTH.-Pedal 3 in. and 2 in.
Hand 3¼ in.
SQ. IN. PER TON LADEN.-290
WHEELS-Michelin fixed wood with detachable rims
TYRES.-Michelin 895 x 835 front and rear

Date	*Event*	*Course*	*Speed*	*Lap Speed*
23/7/11	Grand Prix de France ..	Le Mans	56.5 m.p.h.	67.75 m.p.h.

EXAMPLE No. THREE

The 1912 Peugeot

DURING the early period of motoring, Messrs. Peugeot Freres were entirely concerned with the production of small light cars, so that although they had competed in racing events since 1890 they were not amongst the entrants in the first three Grand Prix. They continued, however, to compete in many Voiturette races, using cars powered by single cylinder or narrow angle V twin engines with exceptional stroke/bore ratios.

In 1911 the Company entered a team for the Grand Prix de France organised by the Sarthe Club, in which event there was a class for cars having four-cylinder engines with a maximum bore and stroke of 110 x 200 mm. In deference to the wishes of the French Manufacturers' Association this project was not completed, but it seems probable that some preliminary design work was carried out during the year which was also remarkable for the advent of Zuccarelli, an engineer who had made his name as a racing driver with Hispano-Suiza.

Zuccarelli made a third with Georges Boillot and Jules Goux and they persuaded Robert Peugeot to let them build a team of cars with 110 x 200 mm. four-cylinder engines for 1912 Grand Prix racing in the Lion-Peugeot works at Belfort. They secured the services of a young Swiss engineer called Henri, who was charged with the task of interpreting their many ingenious ideas on paper and extending them into the realm of working practice, and the result was without doubt the most advanced racing car constructed up to that time, many features of which persisted for more than a decade and some of which had an influence on racing from that day to this. In particular, the general construction embodied in the various sizes of the 1913-14 Peugeots followed directly from the 1912 cars and markedly influenced the 1914 Sunbeam and Humber racing cars, the 1919-22 Ballot designs and the 1921-23 Sunbeams and Talbot Darracqs.

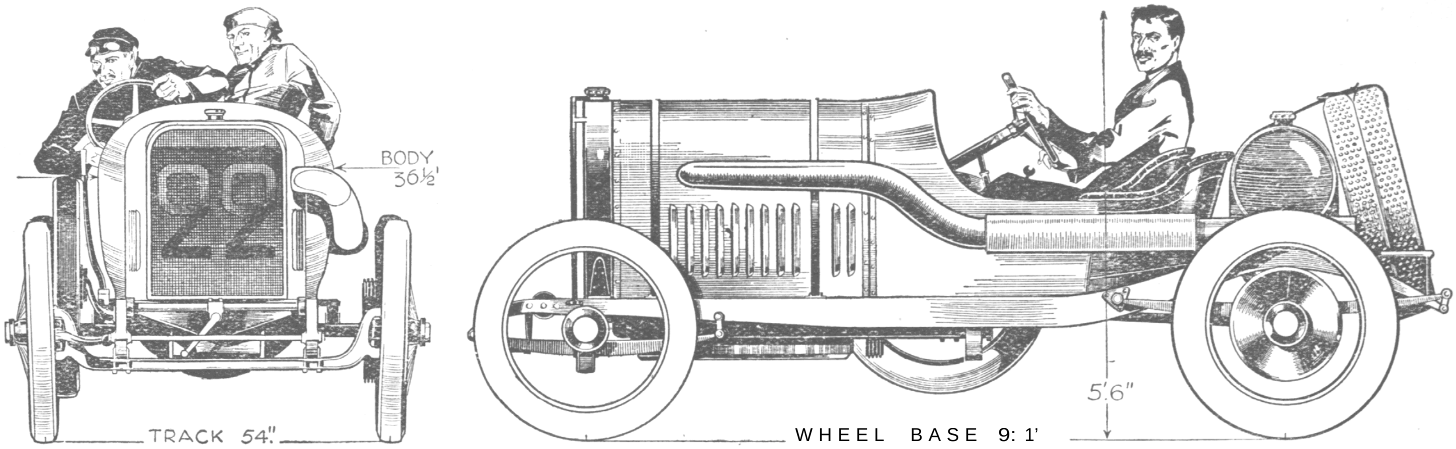
The car now to be described was driven by Boillot to win the 1912 Grand Prix on the Dieppe Circuit at 68.5 m.p.h., and the 1913 Indianapolis race with Goux at the wheel at 75.92 m.p.h.

So far as is known no car survives for inspection and measurement but, fortunately, a search has revealed a number of details and the Peugeot Company have adequate photographic records, although no drawings.

A glance at the perspective drawing accompanying this chapter reveals a characteristically modern feature, viz.: twin camshafts operating four inclined valves per cylinder. Multiple valves, inclined valves and an overhead camshaft had all been used in various combinations prior to 1912, but Henri was the first to combine all the three features just mentioned and a patent was claimed.

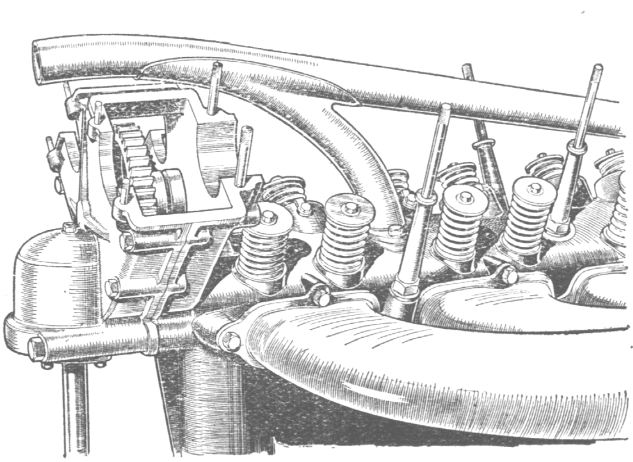
A detail drawing shows that each camshaft was enclosed in an aluminium tunnel split longitudinally and supported from the cylinder head by studs which acted as distance pieces. Projecting from the cover was a tappet running through a bronze guide and forming a complete circle surrounding the cam. This tappet had its own return spring and the entire mechanism was fully enclosed and pressure lubricated.

The valves and valve springs were exposed with the idea of giving good improved cooling and complete immunity from leaks from the cam box down the guide into the cylinder.

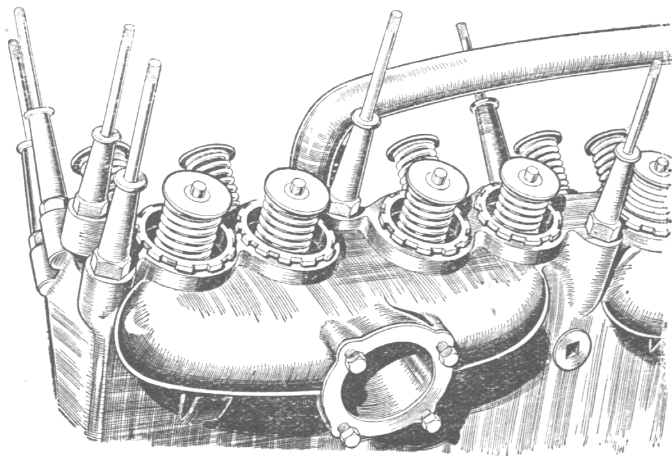


Front and side elevation dimensions (Scale 1 : 30)

The valves themselves were of identical diameter and lift, viz. : 54 mm. and 10 mm. respectively, and although the valve timing is not now available it is known that overlap was employed. The exhaust valves were seated directly in the head, but the inlet valves were carried in detachable cages. The sparking plug was centrally mounted in the cylinder head and all the cylinders and the head formed in one block from an iron casting, both novel features in racing car design at this period.

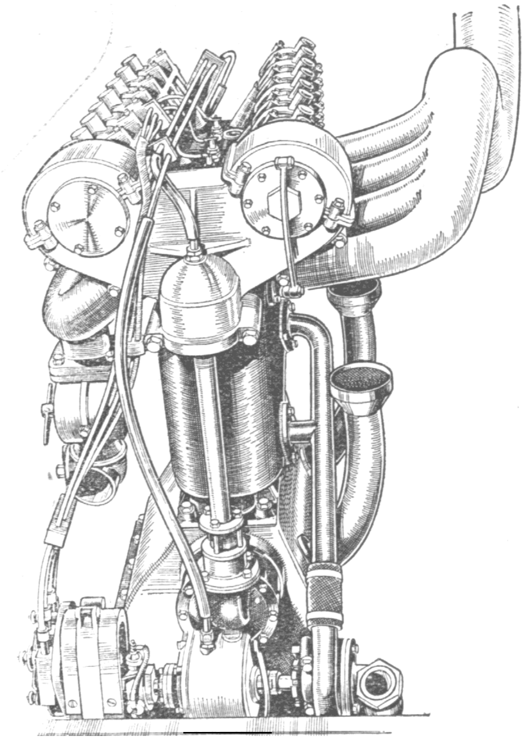


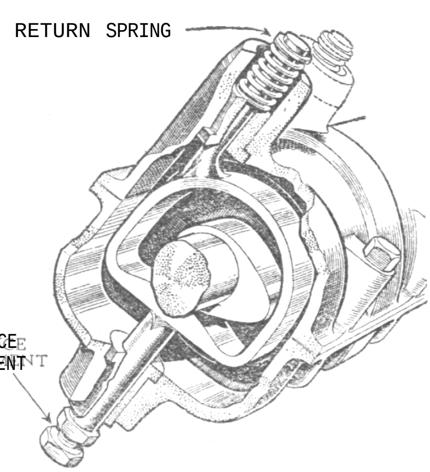
Details of twin-camshaft drive



Rear end and carburetter intake

The block was bolted on to a two-piece light alloy crankcase split on the centre line of five plain main bearings. A flat ribbed sump was bolted to these primary castings, the forward part of which contained a conical seating against which a detachable gear type oil pump was pulled up to make an oil-tight joint. This pump was driven from an extension of the auxiliary drives, comprising a bevel gear leading to the vertical cam-shaft drive, a worm gear driving a cross-shaft to the Bosch magneto on the offside of the car, and the water pump on the nearside.

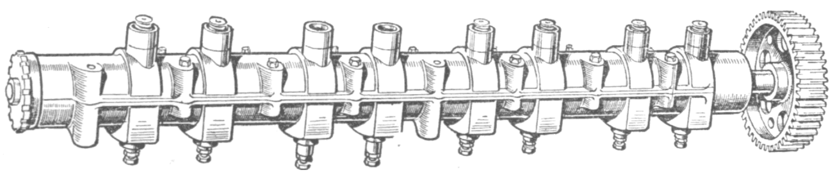




Above-Details of the tappets and their return springs

Left-The engine was pump-cooled by a centrifugal pump driven by a cross-shaft at the front

Right- The camshafts were contained in aluminium tunnels



The cylinder block was mounted markedly *désaxe* in relation to the crankshaft with a view to reducing thrust losses in the pistons, these last being of steel, weighing 32 ounces, and having two narrow rings. The gudgeon pin was locked into the connecting rod boss by a set pin and the connecting rod passed through closely fitting baffles mounted in the top half of the crankcase, which also had detachable inspection plates so that the interior condition of the engine could be quickly examined.

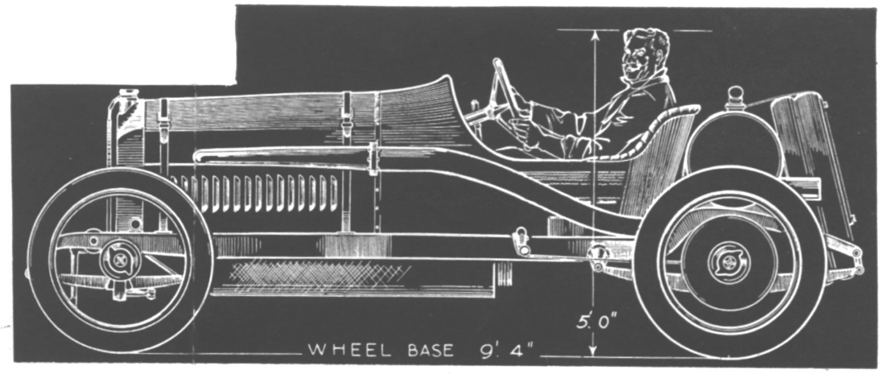
Water circulation was carefully arranged with coolant entering the pump at the base of the block on the exhaust side and emerging through carefully proportioned riser pipes placed on the exhaust side between cylinders Nos. 1 and 2 and 3 and 4. Each pair of exhaust valves discharged into a common port with four ports in all, but a short integral manifold cast in the block served the front and rear pairs of cylinders.

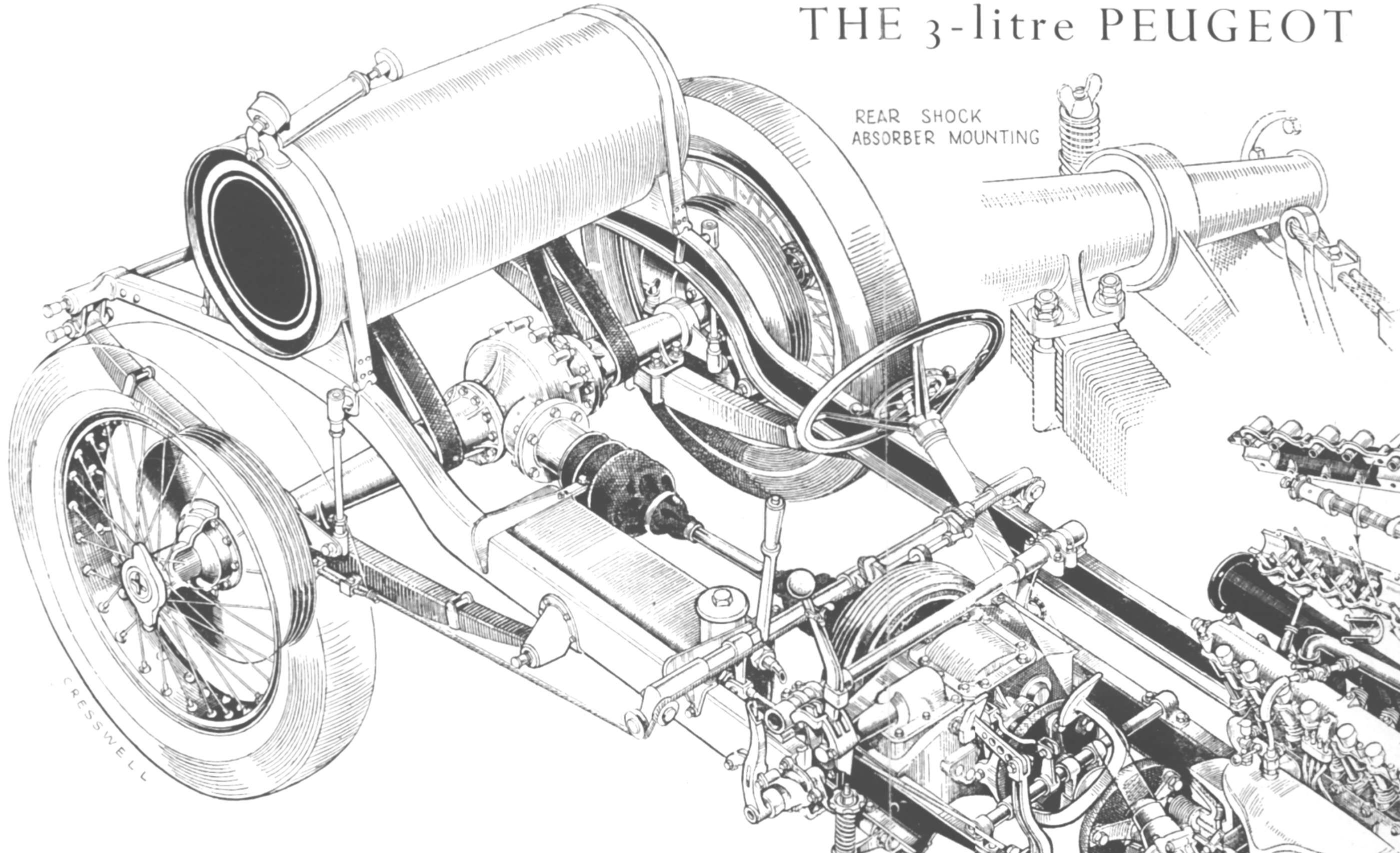
Reliable figures concerning the power output of this engine are hard to find, figures quoted contemporaneously falling between 148 and 175 b.h.p., the latter being the maker's claim. There are good reasons for believing that the lowest of these figures is something of an exaggeration and a reasonable, if conservative, estimate would be 130 b.h.p., that is to say, approximately the same gross output as was obtained on the 1908 Grand Prix cars. Whereas, however, these had been of approximately 12-litres capacity and 120 sq. in. of piston area, Peugeot power was secured with one-third less capacity and half the piston area.

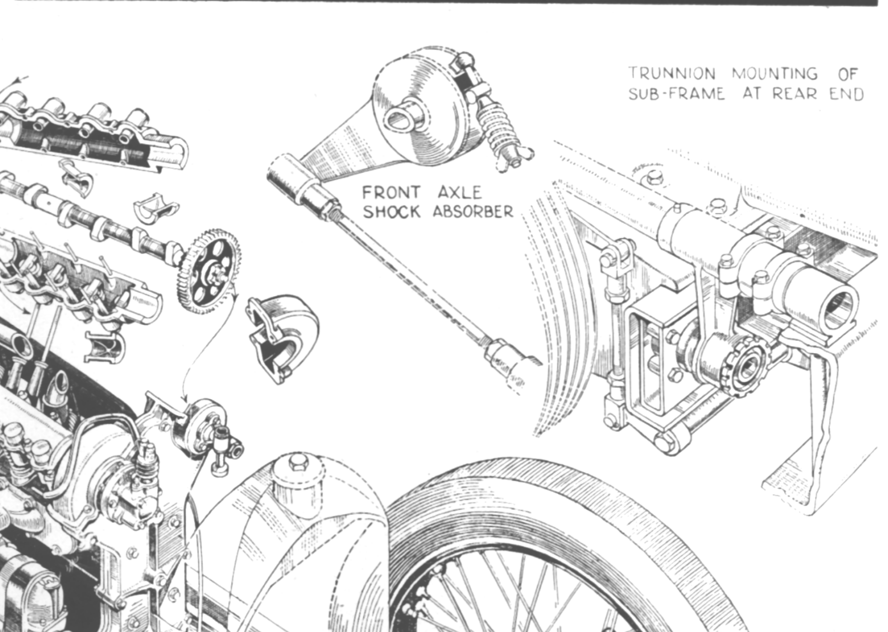
This followed from a big increase in r.p.m. and piston speed, features inevitably tied together by the remarkably high stroke/bore relationship.

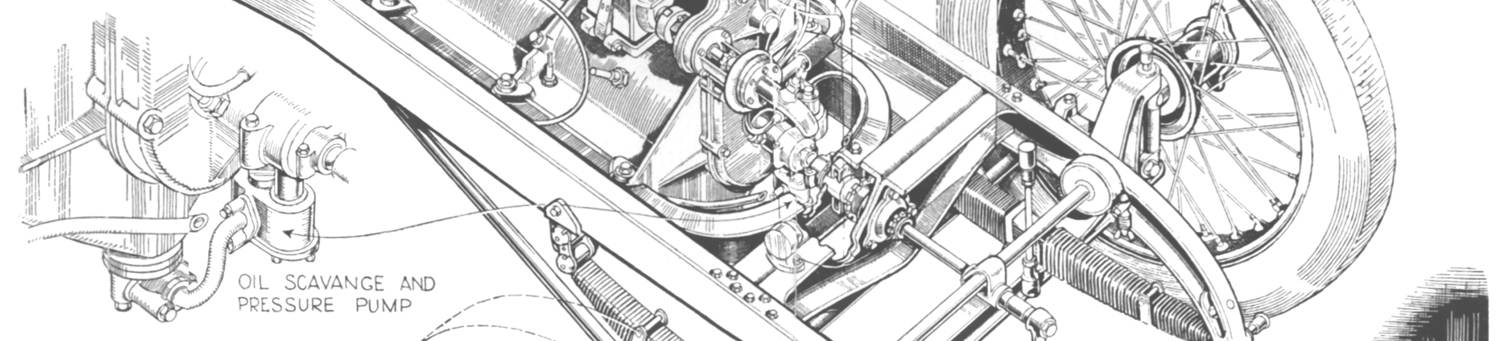
EXAMPLE No. FOUR

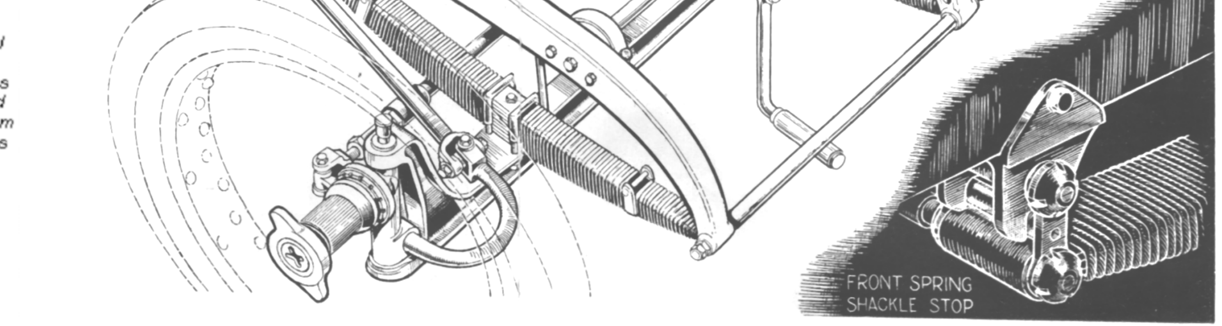
THE 3-litre PEUGEOT

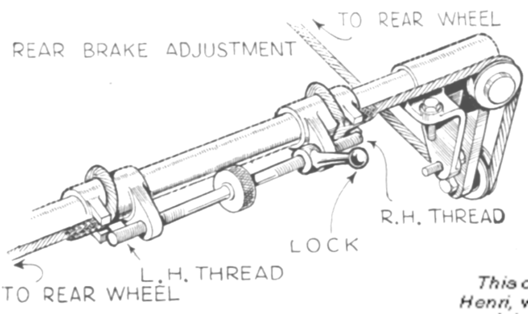


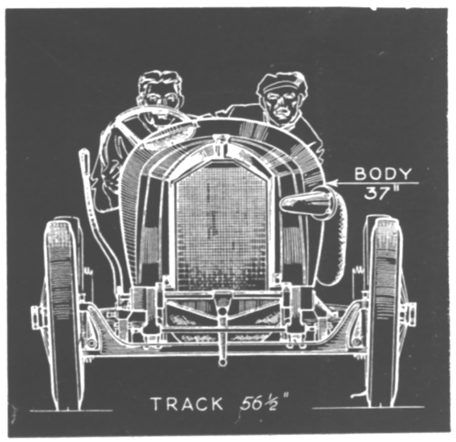












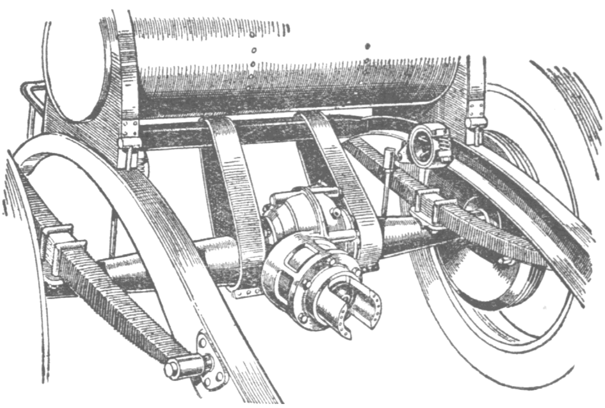
This car, designed by a Swiss engineer, Henri, was easily the most efficient racing model of its time and able successfully to compete with Grand Prix types with double the engine capacity. The engine developed 90 b.h.p. at 2,800 r.p.m., and the car weighed less than one ton in racing trim, so that it had high acceleration and a maximum speed of not far short of 100 m.p.h. On the Indianapolis track it averaged 83 m.p.h. for 200 miles and 80 m.p.h. for 500 miles. Outstanding technical features shown in this drawing include the two overhead camshafts operating four valves per cylinder with exposed valve springs; the single oil pump which sucked oil from the crankcase and circulated it back to the engine through a sealed tank on the driver's side of the chassis and the manner in which the engine was isolated from the effect of chassis distortion by mounting it in a sub-frame which was attached to the main frame through three trunnion bearings. The four-speed gearbox was also attached to the sub-frame and drove the exceedingly light rear axle through a propeller shaft having double universal joints, the torque reaction being taken through the rear springs. The body was designed to be as light as possible and to carry two spare wheels with minimum overhang, as on a 33-mile circuit it was not possible to rely on wheel changing at the pits only.

The success of this car had a great influence on other makes and similar designs were produced between 1914 and 1920 by Sunbeam, Humber, Straker-Squire, the American Monroe, and, to a lesser extent, the Bentley.

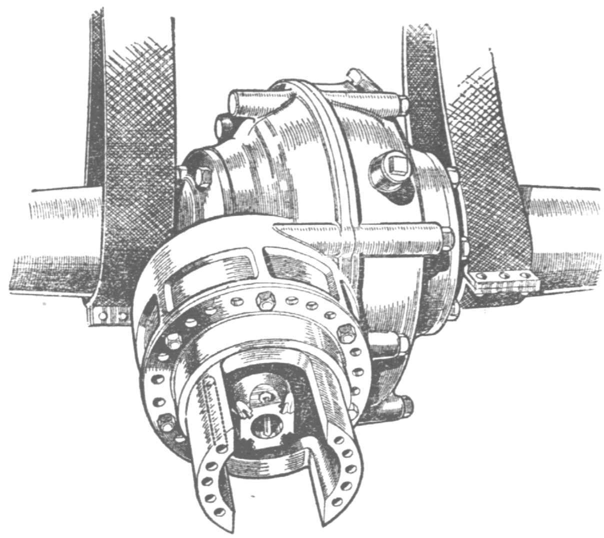
All previous Peugeot racing experience had been with extremely long stroke engines, but there is reason to believe that the 1911 regulations were primarily responsible for the proportions chosen. As an indirect consequence it was possible to provide a compact combustion chamber with a relatively high compression ratio and a high useful swept volume per minute with no excessive r.p.m. or valve openings per minute. The choice of four valves per cylinder was part of an effort to achieve maximum valve area in the face of the comparatively small cylinder diameter.

The engine mounting was in itself unusual, the whole unit being carried in a sub-frame of channel steel shaped in the form of a very elongated U. The opening end was attached to the main frame by ball and socket joints at the back and connected to a cross member beneath the radiator by a trunnion bearing at the front. The engine was thus isolated from any strain imposed by chassis deterioration.

Both frame design and springs were conventional, straight sided channel section being used for the former and semi-elliptic springs fore and aft. The frame was, however, unusually well cross-braced at the front end. The springs, in addition to being exceptionally long and flat were used to transmit the torque from the live rear



The rear axle scaled only 2 cwt. complete and even the rear universal joint was drilled for lightness.



axle. The Peugeot had, in fact, what is known as Hotchkiss drive, whereas all the previous high powered cars had employed either chain drives (for reasons described in the 1911 Fiat) or a live axle in which the torque was transmitted through radius arms or a torque tube. It is now recognised that the Hotchkiss system is a preferred layout in that it produces the minimum of rear-axle steering.

The gearbox, giving four forward speeds, was mounted in the centre of the car and used very short shafts so as to have the minimum deflection. A large ribbed external contracting brake was fitted directly behind the gearbox. The open propeller shaft had pot-type universal joints.

Every endeavour was made to lighten the rear axle as much as possible, and the total weight was only 225 lb. The centre portion consisted of two light alloy castings enclosing the pinion, the crown wheel being rigidly mounted in an extension of the offside housing, as shown in a drawing. Very large diameter internal expanding brake drums were fitted to the rear axle, these being controlled from the hand lever.

Rudge-Whitworth detachable wire wheels were used, this again being an innovation as in all previous Grand Prix races they had been barred by regulations. No attempt was made to streamline the body, and although the engine capacity was moderate compared with preceding cars the extreme dimension for the stroke, plus the height of the valve gear above the cylinder head, imposed a high radiator and bonnet so that there was no possibility of reducing the frontal area.

From the viewpoint of engine output, weight, frontal area and overall performance factors, the Peugeot, indeed, showed little improvement over the cars built four years previous, but the manner of its design created a profound impression amongst European engineers. For example, with three exceptions all subsequent successful road racing cars have embodied the principle of two overhead camshafts operating inclined valves.

DETAILS OF CAR

MAKE.-Peugeot
TYPE.-7.6-litre
YEAR OF CONSTRUCTION.-1911-12
YEARS RACED.-1912-13
DESIGNER.-Henri
WHEELBASE.-9 ft. 1 in.
TRACK FRONT.-4 ft. 6 in.
TRACK REAR.4 ft. 6 in.
HEIGHT TO SCUTTLE.-51 in.
HEIGHT TO DRIVER'S HEAD.-66 in.
FRONTAL AREA.-16 sq. ft.
UNLADEN WEIGHT.-22.5 cwt.
ALL-UP STARTING LINE WEIGHT.-28 cwt.
MAXIMUM SPEED.-100 m.p.h.
SPEED ON INDIRECT GEARS.-90 m.p.h. on Third
" " " " 66 m.p.h. on Second
" 50 m.p.h. on First
H.P. PER SQ. FT.-8
H.P. PER TON UNLADEN.-115
H.P. PER TON ALL-up.-93
BORE.-110 mm.
STROKE.-200 mm.
STROKE/BORE RATIO.-1.82 : 1
NO. OF CYLINDERS-Four
CAPACITY.-7,600 cc.
PISTON AREA.-58.5 sq. in.
B.H.P.-130 at 2,200 r.p.m.
H.P. PER SQ. IN.-2.43
B.M.E.P.-100
PISTON SPEED FT./MIN.-2,880
CYLINDER HEAD.-Cast-iron integral with block
VALVES NO.-Four
VALVES ANGLE.-45 degrees
VALVE AREA INLET.-28.5 sq. in.
VALVE AREA EXHAUST.-28.5 sq. in.
CYLINDERS.-Cast-iron in one block
FUEL.-Petrol
CARBURETTER.-Claude1
SUPERCHARGER.-Nil
MANIFOLD PRESSURE.-Atm.
IGNITION.-BOSCH High Tension Magneto
PLUGS NO.-Four
PLUGS LOCATION.-Vertical in head
CRANKSHAFT.-One-piece no counterbalancing
MAIN BEARING NO.-Five
MAIN BEARING TYPE.-White Metal
BIG END TYPE.-White Metal
LUBRICATION.-Forced, wet sump
CAMSHAFTS NO.-Two
CAMSHAFT LOCATION.-Overhead
CAMSHAFT DRIVE.-Shaft and bevel wheels with final spur wheels
CAMSHAFT DRIVE LOCATION.-Front of crank
CLUTCH.-Multi-plate
GEARBOX LOCATION.-Separate from engine
GEAR RATIOS.-2.3, 2.6, 3.5, 4.7:1
TRANSMISSION.-open propeller shaft, two universal joints, live axle with Hotchkiss drive.
FRAME-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBERS.-Hartford friction
BRAKE SYSTEM.-Mechanical. Foot : to external contracting band behind gearbox. Hand : to internally expanding shoes on rear wheels
BRAKE DRUM DIAMETER.-18 in. approx.
BRAKE DRUM WIDTH.-No data
SQ. IN. PER TON LADEN.-No data
WHEELS.-Rudge-Whitworth detachable
TYRES-Continental, 895 x 135 Rear, 875 x 120 Front

RACING RECORD OF THE 1912 PEUGEOT

Date	*Event*	*Course*	*Speed*	*Lap Speed*
25/6/12	French G.P.	Dieppe	68.45 m.p.h.	75 m.p.h.
9/9/12	G.P. de France.	Dieppe	71.65 m.p.h.	80 m.p.h.
30/5/13	500 Mile Sweepstake	Indianapolis	75.92 m.p.h.	93.5 m.p.h.

EXAMPLE No. FOUR

The 1913 3-Litre Peugeot

HENRI, once again in association with Messrs. Boillot, Goux and Zuccarelli, designed two Peugeot racing cars for 1913 events. In these he was able to embody all the experience that had been learned with the cars designed for the 1911 Grand Prix, which eventually ran in, and won, the 1912 Grand Prix, as described in Example No. 3.

The larger of these models had a four-cylinder engine with 5.65-litre capacity which won the 1913 French Grand Prix and, in practice, broke the lap record for Indianapolis in 1914 at 99.5 m.p.h., showing that despite the reduction in engine size this car was faster than its predecessor. Even more remarkable from a technical viewpoint was the 3-litre car built for the 1913 Coupe de 1'Auto race. This design was not originally designed as a Grand Prix model, but was so efficient that after winning the aforementioned race with great ease it competed with success against full Grand Prix types in later races. For example, in the 1914 Indianapolis race, it was second to a 1913 Grand Prix Delage and beat six cars which had run in that event, including both factory-entered 5.65-litre Peugeots. Additionally, it broke the Class E kilometre and mile records at Brooklands at 105.81 and 105.36 m.p.h., figures which compare very favourably with the speeds achieved on the 1912 7.6-litre Grand Prix Peugeot which did 107.6 and 106.29 m.p.h. respectively over the same distance.

In breaking these records a single-seater body was used in both cases. In road racing trim the 3-litre car achieved a mean speed of 93.82 m.p.h. over two ways of a kilometre stretch and 95.07 m.p.h. in one direction.

The general construction of the engine is obviously similar to the 1912 type, particularly in respect of the stroke/bore ratio (which was actually increased to 2:l) and the *désaxe* position of the cylinders, the centre line of which was offset 20mm. in relation to the crank centre line. In detail, however, many changes were made. The angle of the four valves per cylinder was increased to 60 degrees and the tappet mechanism between cam and valve stem slightly modified. Additionally, the camshafts were driven by a train of spur wheels from the front of the crank, an extension of this driving a fore and aft shaft connecting to the magneto mounted on the crankcase and a centrifugal water pump mounted between the radiator and the-engine. A skew gear from this shaft drove a single oil pump which performed both scavenge and delivery functions, as will be later described.

The crankshaft showed marked novelty in design and construction. It was counterbalanced and made in two halves bolted at the centre, a construction dictated by the decision to carry the crankshaft in ballbearings. The crank itself was 50 mm. diameter on the journals and 40 mm. on the crankpin, and a double row ballbearing was employed for the centre main with a single row at each end of the crankcase. By this successful use of ballbearings and a high speed engine Henri initiated yet another change which was to have a permanent effect in racing-car design.

It is worth noting that the pinions in the camshaft drive were also mounted on ballbearings and that by removing eight nuts the entire camshaft drive could be

removed. The use of exposed valve springs and valve guides was continued with a view to achieving maximum cooling and complete freedom from the passage of oil down the valve guides.

The inlet and exhaust valves were of equal diameter (40 mm. over the head) and it is worth noting that in accord with modern practice the main casting projected into the ports to give full protection for the valve guides, the ports themselves each being 35 mm. diameter. Both valves were returned by double coil springs, the outer having eight coils of 3 mm. wire and the inner eleven coils of 2 mm. wire. The valve lifts were identical in both cases at 9 mm., but the exhaust cam had a much more violent opening and longer dwell than the inlet. The inlet valve opened after the piston reached top-centre, but there was an overlap of some six degrees.

A fully open valve just cleared the slightly domed top of the piston head, the c.r. employed being 5.6:1.

As on the larger cars the pistons were machined out of solid steel billets with two plain 4 mm. piston rings, whilst the H section steel connecting rods carried plain white metal bearings.

The connecting rod measured 261 mm., i.e. stroke x 1.6, tapered slightly from 25 mm. to 16 mm. at the neck and the gudgeon pin was only 13 mm. diameter or less than 17 per cent of the bore. The top of the rod was split and compressed by a set pin to give positive locking for the gudgeon pin.

The lubrication system on the car was of particular interest. The earliest racing engines had been supplied with oil under gravity from a remote tank, but with increasing output and rotational velocities this scheme gave way to full pressure lubrication with the oil contained in the crankcase. The 1913 Peugeot scheme was one of the first to employ a dry sump system and is of particular. interest in that only one oil pump was used. This drew either oil or air from the base of the crankcase ; if the former it was delivered through to a large capacity tank mounted beneath the driver's seat, this tank being provided with an air-tight filler cap. If no oil was available from the sump the pump delivered air under pressure to the tank, which was thus held under a constant pressure from the pump. This drove the oil from the tank through a single pipe to six sight feeds mounted on the dashboard. Oil passed through these in a constant stream ; their purpose was to make clear to the driver and mechanic that oil was being despatched to the various lubrication points of the engine. The six offtake pipes led to the camshafts, the pump and magneto shaft, the main bearings and the camshaft drive, and each system could be pre-set so as to divide the flow in accordance with requirements. The oil delivered to the main ballbearings was collected in rings in the crankshaft and fed by centrifugal force into the big end bearing.

This system had the advantage of cool oil stored well away from the crank chamber, formed a visible assurance that the oil flow was correct and gave the opportunity of adjustment between one point and another. To prevent oil tank pressure flooding the sump when the engine was brought to rest there was an ingenious interconnection between the ignition switch and a cock on the main oil line to the sight feed. By this means the tank was isolated from the engine when the magneto was switched off.

The crankcase was of unusual design in that it was not split on a horizontal plane, but was a one-piece casting of barrel section. The two ends were enclosed by

plates which supported the front and rear ball bearings, the centre main being fed into an accurately machined housing in a dividing wall between the front and rear halves of the crankcase. This design improved the stiffness of the bottom half of the engine very considerably, and was used on all subsequent Henri designs up to 1922, and on other racing cars until 1936.

Carburation was from a single vertical Claude1 instrument feeding into a Y-shaped pipe, the exhaust manifold having individual take-offs for each pair of exhaust ports. All the cooling water was delivered to the exhaust side of the cylinder block and was then taken back to the radiator through two offtake pipes mounted in the centre part of the cylinder head but biased towards the exhaust side thereof. The system contained three gallons of water, 30 per cent of which was contained in the cylinder jackets and pipes.

Both engine and gearbox were mounted in a U section sub-frame which represented a refinement upon the scheme originally used on the 1912 cars. The engine and gearbox unit could, therefore, be aligned on this frame before it was installed in the chassis, the detail arrangements between the two being shown clearly in an illustration.

The 3-litre car was remarkable for the use of a cone clutch, and although the gearbox was of orthodox design it is worth noting that in an effort to save weight all the shafts were bored out. Similar pains in the saving of weight were taken in the construction of the rear axle in which the thickness of the steel outer members was brought down to a few millimetres, both being bolted to a differential housing formed in two light alloy casings.

The suspension was by semi-elliptic springs fore and aft. It is noteworthy that the rear shock absorbers were mounted directly on the rear axle, an arrangement which increased unsprung weight very slightly and offered substantial gains in mechanical simplicity. The front axle was chiefly notable for the use of positive trail to the king pins.

The braking system was entirely conventional, being formed with an internal expanding transmission brake placed just after the gearbox and a handbrake connecting to internal expanding shoes in the rear brake drums. A highly ingenious system of adjustment for the latter was embodied, it being actually possible for the mechanic to compensate for wear in the rear drums whilst the car was in motion. Two steel cables from the brake levers were brought through the frame and ran round two pulleys to end in a sleeve having free movement on a tubular cross-shaft. Each of the two sleeves had a short projecting boss threaded to a long spindle with a right- and left-hand thread. The centre of this spindle was enlarged to form a knurled nut and at one end there was a locking lever. By lifting a small cover in the floorboards the locking lever could be released and the spindle turned so as to bring the two sleeves together and to take up quite quickly the slack in the rear brake cables.

As on previous Peugeot racing cars no effort was made to streamline the bodywork, but due to the considerably smaller size of the car and engine the frontal area was reduced to 14½ sq. ft., so that in conjunction with the low weight of the car satisfactory figures for h.p. per sq. ft. frontal area and h.p. per ton were maintained.

In addition to their performance, these cars were astonishingly reliable and they set a trend in design which lasted for many years. In the R.A.C. T.T. races of 1914 both the Straker-Squire and Humber engines were obviously inspired by Henri’s 1913 design, whilst the Sunbeam cars which won the race were an interchangeable replica

thereof, as the Sunbeam designer, L. Coatalen, bought one of the Peugeot cars through an intermediary and imported it to England as a model. The 1914 Grand Prix Sunbean 4Q-litre cars were enlarged editions of the T.T. model, whilst the American Monroe design which won the Indianapolis race of 1920 obviously owed much to Peugeot influence.

DETAILS OF CAR

MAKE.-Peugeot
TYPE.-Coupe 1'Auto
YEAR OF CONSTRUCTION.-1913
YEARS RACED.--1913-14
DESIGNER.-Henri
WHEELBASE.-9 ft. 4 in.
TRACK FRONT.-4 ft. 8½ in.
TRACK REAR.-4 ft. 8½ in.
HEIGHT TO SCUTTLE.-53 in.
HEIGHT TO DRIVER'S HEAD.-60 in.
FRONTAL AREA.-14.5 sq. ft.
UNLADEN WEIGHT.-16 cwt.
ALL-UP STARTING LINE WEIGHT.-21 cwt.
MAXIMUM SPEED.-95 m.p.h.
SPEED ON INDIRECT GEARS.-70 m.p.h. on Third
„ „ „ „ 45 m.p.h. on Second
30 m.p.h. on First
H.P. PER SQ. FT.-6.2
H.P. PER TON UNLADEN. 113
H.P. PER TON ALL-UP.-86
BORE.-78 mm.
STROKE.-156 mm.
STROKE/BORE RATIO.-2.2 : 1
CAPACITY.-2,980 c.c.
PISTON AREA.-29.4 sq. in.
B.H.P.-90 at 2,900 r.p.m.
H.P. PER SQ. IN.-3.06
B.M.E.P.-134 lb. sq. in.
PISTON SPEED FT./MIN.-3,000
CYLINDER HEAD.-Cast-iron integral with block
VALVES No.-Four
VALVES ANGLE.-60 degrees
VALVES AREA INLET.-15.6 sq. in.
VALVE AREA EXHAUST.-15.6 sq. in.
CYLINDERS.-Cast-iron in one block
FUEL.-Petrol
CARBURETTER.-Claude1
SUPERCHARGER.-Nil
MANIFOLD PRESSURE.-Atm.
IGNITION.-Mea high tension magneto
PLUGS No.-Four
PLUGS LOCATION.-Vertical in head
CRANKSHAFT.-Two-piece counterbalanced
MAIN BEARING No.-Three
MAIN BEARING TYPE.-Ball
BIG END TYPE.-White metal
LUBRICATION.-Dry sump
CAMSHAFTS No.-Two
CAMSHAFT LOCATION.-Overhead
CAMSHAFT DRIVE.-Train of spur gears
DRIVE LOCATION.-Front of crank
CLUTCH.-cone
GEARBOX LOCATION.-Separate from engine
GEAR RATIOS.-3.4, 4.8, 7.4 and 11:l
TRANSMISSION.-open propeller shaft, two universal joints, live axle with Hotchkiss drive
FRAME.-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBERS.-Hartford friction
BRAKE SYSTEM.-Mechanical. Foot to internal expanding shoes on transmission. Hand, to internal expanding shoes on rear wheels
SQ. IN. PER TON LADEN.-380
WHEELS.-Rudge-Whitworth detachable
TYRES.-Pirelli, 895 x 135 Rear, 785 x 105 Front

RACING RECORD 1913 3-LITRE PEUGEOT

Date	*Event*	*Course*	*Speed*	*Lap Speed*
21/9/13	*Coupe* de SAuto	Boulogne	63.15 m.p.h.	65.6 m.p.h.
30/5/14	500 Mile Sweepstake	Indianapolis	SO.89 m.p.h. (2nd)	—

EXAMPLE No. FIVE

The 1914 Mercedes

THE Mercedes cars constructed by the Daimler Motoren Gesellschaft Unterturkheim, were amongst the most prominent competitors in the early history of motor racing.

The 60 h.p. type, driven by Camille Jenatzy, won the 1903 Gordon Bennett race and the 90 h.p. models were second, third, fifth and eleventh in the 1904 Gordon Bennet; event. In the first Grand Prix race of 1906 two cars finished tenth and eleventh ; in 1907 one finished tenth ; and in 1908 Salzer broke the lap record and Lautenschlager finished first and Poege fifth.

The Daimler Motoren-Gesellschaft directors then decided to withdraw support for racing and made no effort to reconsider their verdict until 1913. In this year they made an indirect approach by building some cars for their Belgian agent, Pillette, who entered them for the A.C.F. Grand Prix and the Grand Prix de France run by the Sarthe Club at Le Mans. Under the rules manufacturers alone were eligible for the A.C.F. race, in which entry was refused, but the cars ran in the Sarthe event from which much experience was gained. Although contemporary reports ascribed a mixture of chain and shaft drive to these entries none of the cars in fact used a live axle and they were therefore the last chain-drive models designed for Grand Prix racing. Some had four- and some six-cylinder power units and although one sleeve valve four-cylinder was run, the other three engines were largely based upon existing aircraft engines having a single overhead camshaft (driven by a vertical shaft in the rear) and inclined valves operated by exposed rockers. One of the engines used cylinders constructed from steel forgings with welded-up ports and sheet-steel water jackets.

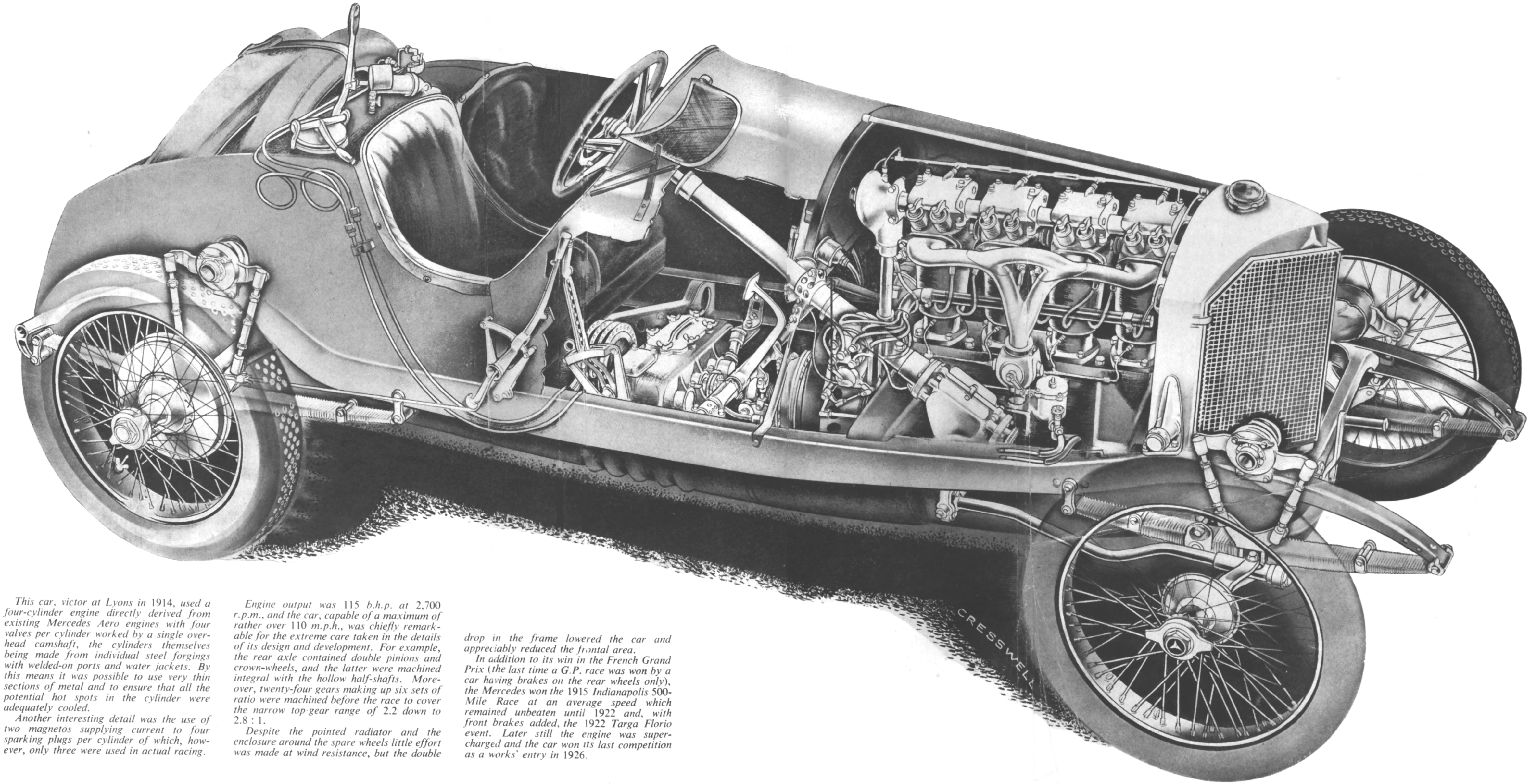
There is no doubt that the data gained with these cars was of considerable value to constructors when they entered a team for the 1914 A.C.F. Grand Prix, the regulations of which stipulated a maximum engine capacity of 4½ litres unsupercharged and maximum weight of 21 cwt. bare.

Mercedes decided to build cars with four-cylinder engines and live axles, and to enter the largest team permitted, viz., five cars. Despite the knowledge that other constructors would be incorporating such advanced features as double overhead camshafts and front-wheel brakes, the German models were conservatively engineered. The engineers made full use of the experience obtained by the aviation engine section of the business, but there were, of course, a number of deviations embodied with a view to increasing the r.p.m. and the power per litre. In particular the need for a large valve area led to the use of four valves per cylinder, together with two magnetos and a choice of three or four sparking plugs ; additionally, in order to avoid critical torsional oscillations the vertical drive to the camshaft and the cross drive to the magnetos was placed at the rear of the engine, adjacent to the flywheel.

In a works' publication, issued in 1938, the constructors estimated the speed of this car as 112 m.p.h., whilst in a prior publication of 1915 they recorded that the cars would do 103 m.p.h. when they left the works, which was improved to 120 m.p.h. at the time of the race. It is possible to check these figures against an average of 103.45 m.p.h. for fifty miles in the U.S.A. on a board track and 109 m.p.h. for a single lap.

EXAMPLE No. FIVE

THE 1914 MERCEDES



This car, victor at Lyons in 1914, used a four-cylinder engine directly derived from existing Mercedes Aero engines with four valves per cylinder worked by a single overhead camshaft, the cylinders themselves being made from individual steel forgings with welded-on ports and water jackets. By this means it was possible to use very thin sections of metal and to ensure that all the potential hot spots in the cylinder were adequately cooled.

Another interesting detail was the use of two magnetos supplying current to four sparking plugs per cylinder of which, however, only three were used in actual racing.

Engine output was 115 b.h.p. at 2,700 r.p.m., and the car, capable of a maximum of rather over 110 m.p.h., was chiefly remarkable for the extreme care taken in the details of its design and development. For example, the rear axle contained double pinions and crown-wheels, and the latter were machined integral with the hollow half-shafts. Moreover, twenty-four gears making up six sets of ratio were machined before the race to cover the narrow top gear range of 2.2 down to 2.8 : 1.

Despite the pointed radiator and the enclosure around the spare wheels little effort was made at wind resistance, but the double drop in the frame lowered the car and appreciably reduced the frontal area.

In addition to its win in the French Grand Prix (the last time a G.P. race was won by a car having brakes on the rear wheels only), the Mercedes won the 1915 Indianapolis 500-Mile Race at an average speed which remained unbeaten until 1922 and, with front brakes added, the 1922 Targa Florio event. Later still the engine was supercharged and the car won its last competition as a works' entry in 1926.

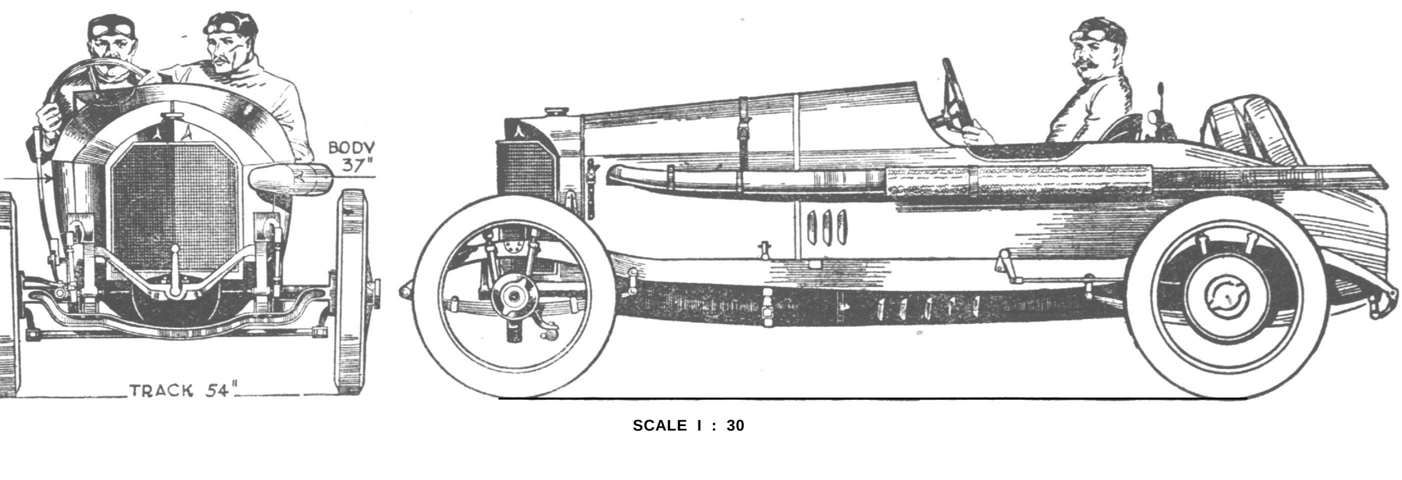
The Brooklands times achieved by one of these cars in 1921 give a flying lap at 104.19 and a standing lap at 84.46, and, on the balance of evidence, it is reasonable to place the top speed of this car at 112 m.p.h.

In using four valves per cylinder the designer followed the example set by Henri, of Peugeot, two years before, but by using a single camshaft with exposed rockers a certain degree of simplicity was obtained.

There was nothing in the general specification of the car to mark it out from many of the other forty entrants comprising the field, but the execution of the design was engineering of the first order and proof that the palm of victory goes more often to the designer who avoids foolishness than to the one who shows the greatest ingenuity.

Probably the most interesting feature of the engine, both in itself and in its influence upon subsequent designs, was to be found in the cylinder construction. Between 1900 and 1905 many cars had separately cast cylinders with, in some cases, electrically deposited sheet-copper water jackets. Subsequently it became more usual to have cylinders cast in pairs and, finally, in blocks of four, a system which undoubtedly added considerably to the stiffness of the engine as a whole. Mercedes, however, retained pairs of cylinders on their 1911 and '12 aero engines, and in the latter year developed a construction in which the cylinders were made from steel forgings, the ports and water jackets being subsequently welded into position.

The 1914 racing car engine followed this practice, but instead of mounting the cylinders on the crankcase in pairs welded together they were separately attached. Maintenance was probably improved by this scheme at the expense of rigidity, but there can be no question concerning the merits of the basic system of construction.



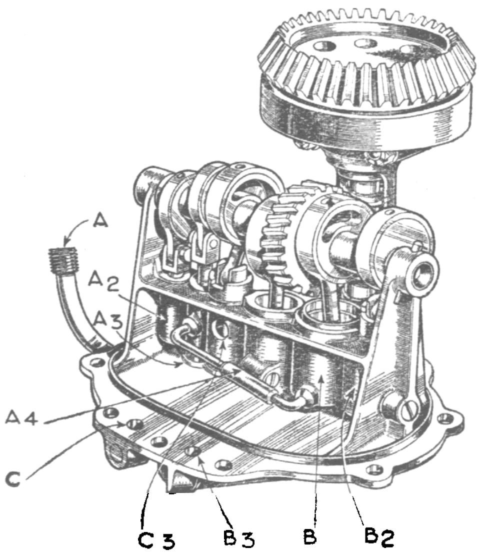
SCALE 1 : 30

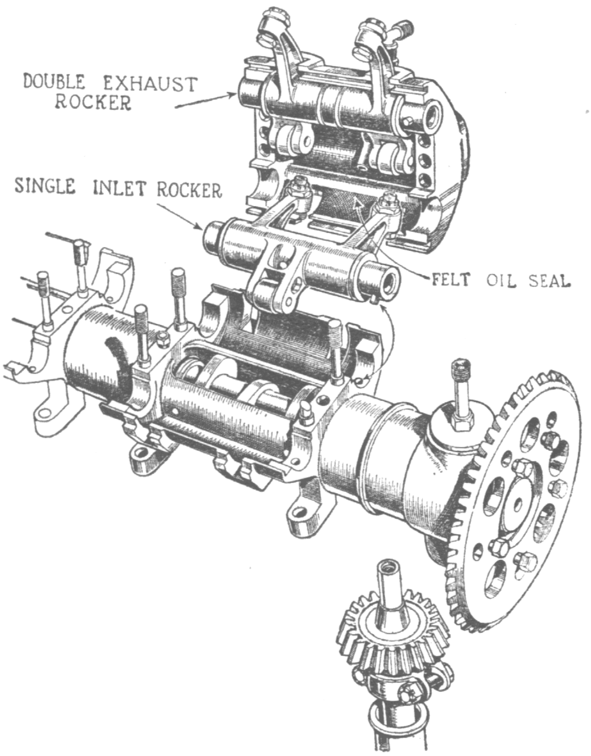
It is, of course, expensive in man-hours and requires highly expert welding, but it has the great technical merit of giving close control over the thickness of metal of every part and in particular makes it very easy to get water very close indeed to the valve seats. The valve gear on the racing car engine was also inherited directly from and was virtually a replica of that employed on previous aero engines, except that the number of valves per cylinder were increased to four, inclined at an included angle of about 60 degrees and with a timing as follows :

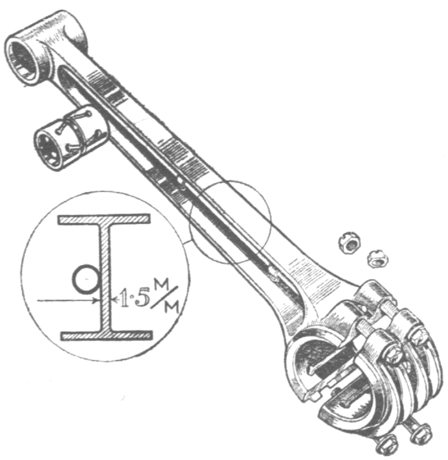
Inlet opens T.D.C.	Exhaust opens 50 degrees before B.D.C.
Inlet closes 35 degrees after B.D.C.	Exhaust closes 9 degrees after T.D.C.

All the valves are operated from a single overhead camshaft which runs in bronze bearings. Three cams per cylinder are provided, one operating the inlet valves through a forked rocker and the other two working on a rocker for each exhaust valve. The camshaft is mounted in a long tunnel running along the top of the engine with the rockers emerging through slots in the rocker box, the upper part of the valve stem and springs being entirely exposed with a view to giving maximum cooling and instant accessibility for checking valve clearances.

The camshaft drive consisted of a vertical shaft at the rear of the engine with bevel drive top and bottom, a cross-shaft providing drives for two Bosch magnetos one of which was a double magneto feeding eight sparking plugs on the carburetter side of the cylinders, the other feeding four plugs, i.e. one per cylinder on the exhaust side. Although provision was made for the use of sixteen sparking plugs, in all only twelve were actually used, all of them threaded horizontally into the combustion space. At the opposite end of the engine a vertical shaft, driven by bevel gears, connected to water pump, the offtake of which leads to a manifold delivering coolant to the base of







Above-Details of camshaft, rocker gear and camshaft drive

(Above Left)-The triple pump lubrication unit (vide text)

Left-Connecting rod showing big and little ends

each four water jackets, an interesting point being that these were carried almost the full length of the cylinder barrels. These were attached to the crankcase by four bolts which pass right through the main-bearing housings and serve at their opposite extremity

as tie bolts for the main bearing caps. The crankshaft (48 mm. in diameter) was well counterbalanced, and ran in white metal bearings.

Two piston-type pumps with slide valves attended to the lubrication of the engine, but one of these (C) was a scavenger which sucked oil from the front end of the sump and delivered it into the rear half of the crankcase. The second piston (B) picked up oil from the rear of the sump and delivered it through a filter to the main bearing big ends and, by small pipes fitted on to the connecting rods, to the gudgeon pins. This, however, did not entirely complete the oil pump unit for a third piston (A) abstracted a small quantity of oil on each stroke from a reserve tank and delivered it into the suction side of the main oil pump. By this means the sump level was kept approximately constant and, perhaps more important, the oil stream going to the bearings was constantly refreshed by a supply of cool, clean oil. Supplementing this mechanical system was a pump operated by the mechanic's foot which could deliver oil either to the valve gear or to the crankcase at will. This delivered oil direct to the base of the cylinders, the camshaft bearings and the rockers.

The big ends were also white metal cast into detachable bronze shells, the rods themselves being particularly fine examples of the machinist's art with the web only 1.5 mm. thick. These components were nevertheless a source of weakness on the design, almost eliminating the 1915 Indianapolis winner, in which race de Palma had to finish on three cylinders. At the top end of the rod the gudgeon pin was locked in the boss with a floating bush interposed between pin and the little end.

The gudgeon pin ran in a cast-iron piston which had four very narrow rings, an interesting detail of the design being the oil return groove between Nos. 3 and 4 rings. This consisted of a shallow recess with knife edges and small holes drilled through for oil return purposes.

The crankcase was formed from two light alloy castings giving a four-point mounting in the frame, and it will be appreciated from the description of the main bearings that the bottom half was merely an oil container, all the stresses being taken through the upper half which also acted as a considerable stiffening element in the front end of the frame. The carburation on these engines was by a special Mercedes type instrument with a barrel type choke delivering to a Y branch manifold.

Power was transmitted through a highly ingenious double cone clutch, the purpose of which was to give the reliability and simplicity of the cone type coupled with moderate diameter and low spinning weight characteristic of the multi-disc form of transmission.

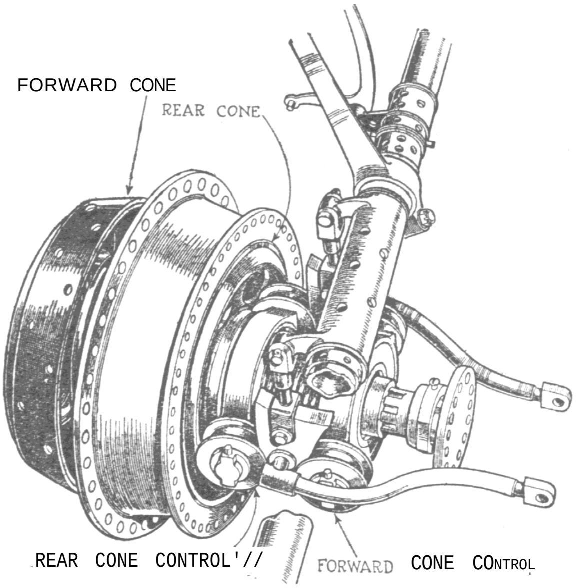
A short shaft was interposed between the clutch and the gearbox of orthodox four-speed type, behind which was a large spherical joint which takes the driving torque and propels the car. The propeller shaft was braced by a triangulated rod layout and the rear axle housing was light and stiff but of fairly orthodox design. Two halves were machined from the solid and held together by eighteen bolts.

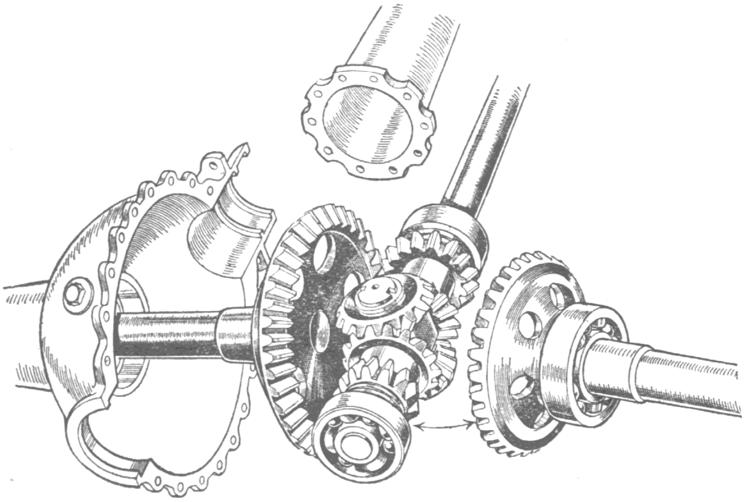
The interior gearing was unusual with two crown-wheels and two pinions each driving one half-shaft. Between them lay the differential gear, and as a consequence the loading on the teeth was light, and, the pinion shaft being between two bearings, it did not deflect in the manner normal to the orthodox overhung design.

This form of construction is the subject of a Mercedes patent in 1899, the stated intention of which was to permit inclined countershafts so that the sprockets driven thereby should be in line with wheels inclined outwards and that the tyre tread would

be more nearly parallel with the road surface when the car was running on the crown of the heavily-cambered roads of the time. Exactly the same principle was followed with the live axle on the 1914 racing car although the degree of inclination was very slight, only 1' 20" from the vertical.

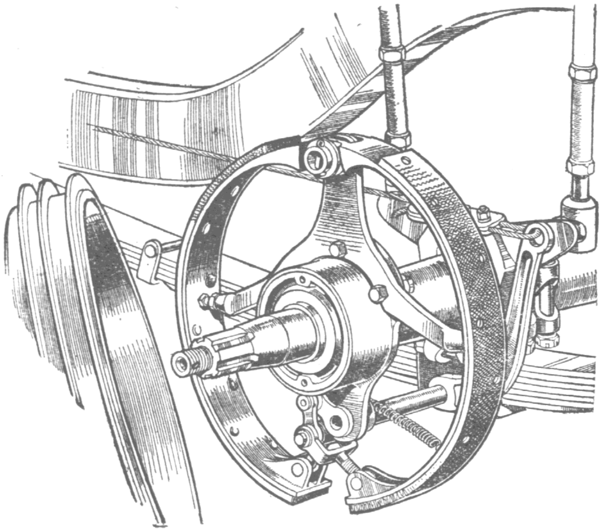
The detail of the rear axle design is yet a further example of the immense thoroughness with which these cars were prepared. The crown-wheel was in one with





Top, left-Clutch assembly

Top, right-Differential assembly



Right-Rear brake assembly

the half-shaft, the latter being hollowed to save weight. Sufficient half-shafts-cum-crown-wheels and pinions were constructed to give a choice of six alternative ratios between 2.2 and 2.7:1. The choice of gear ratios was indeed a severe headache for the designer. The 23.3-mile Lyons circuit was popularly supposed to have 100 corners : it certainly embraced a difference of 700 ft. between the highest and the lowest point, and one leg consisting of an eleven-mile switchback straight.

The external contracting brake on the propeller shaft was worked by the pedal and the hand lever expanded the internal shoes on the rear wheels, not, however through a cam, but by means of a toggle action. The shoes themselves were very thin

and purposely made to distort so as to give a more equal pressure between brake linings and brake drums throughout the whole arc of the shoe.

Semi-elliptic springs were used with special Mercedes shock absorbers, which took the form of supplementary coil springs compressed by a face cam arrangement. The result was to give variable rate to the springing system, stiffening up, of course, as the axle departs from its normal position.

Steering was by means of a massive worm and nut box through a conventional linkage system in which both forked arms and spring-loaded ball joints were employed, whilst the chassis frame was normal steel channel section, but had a double drop so as to give a low centre of gravity.

Another feature of note was an embryo X-bracing member just aft the gearbox. Although the angle of the X was narrow it was of very stout construction and was employed not only to brace the frame, but also to locate the trunnion on the forward end of the torque tube. There was a double thickness of metal in the centre and great care was taken to see that the torque tube mounting was dead square. The frame was also braced by a cross-member under the radiator, by the engine, to some extent by the gearbox, by a light drilled channel section on the up-sweep over the rear spring and by a tubular member connecting the rear spring horns.

Acknowledgments.-Thanks are due to Daimler-Benz A.G., Stuttgart, for co-operation in providing data and drawings relating to the above car, and to Mrs. Ariel Clarke who gave full access to the car driven at Lyons by Pilette then in her possession and now owned by Mr. Briggs Cunningham.

DETAILS OF CAR

MAKE.-Mercedes
TYPE.- 4½ -litre G.P.
YEAR OF CONSTRUCTION.-1914
YEARS RACED.-1914-29
DESIGNER.-Paul Daimler, Nallinger
WHEELBASE.-9 ft. 4 in.
TRACK FRONT.-4 ft. 4½ in.
TRACK REAR.4 ft. 5 in.
HEIGHT TO SCUTTLE.-47 in .
HEIGHT TO DRIVER'S HEAD . - 60 in.
FRONTAL AREA.-13 sq.ft.
UNLADEN WEIGHT.-21.5 cwt.
ALL-UP STARTING LINE WEIGHT.-26½ cwt.
MAXIMUM SPEED.-112 m.p.h. at 2,900 r.p.m.
SPEED ON INDIRECT GEARS.-65 m.p.h. on Third
" " " " 42 m.p.h. on Second
" " " " 28 m.p.h. on First at 3,000 r.p.m.
H.P. PER SQ. FT.-8.9
H.P. PER TON UNLADEN.-107
H.P. PER TON ALL-UP.-87
BORE.-93 mm.
STROKE.-165 mm.
S./B. RATIO.-1.77:1
No. OF CYLINDERS.-Four
CAPACITY.-4,483 c.c.
PISTON AREA.-42 sq. in.
B.H.P.-115 at 2,800 r.p.m.
B.M.E.P.-120 lb.
H.P. PER SQ. IN.-2.73
PISTON SPEED FT./MIN.-3,050
CYLINDER HEAD.-Steel integral with barrel
VALVES No.-4
VALVES ANGLE.-60 degrees
VALVES AREA INLET.-22 sq. in.
VALVES AREA EXHAUST.-22 sq. in.
CYLINDERS.-Separate steel forgings with welded-up ports and water jackets
FUEL.-Petrol
CARBURETTER.-Mercedes
SUPERCHARGER.-Nil
MANIFOLD PRESSURE.-Atm.
IGNITION.-Two Bosch high tension magnetos
PLUGS No.-12
PLUGS LOCATION.-Horizontal, two on inlet, one on exhaust side each head
CRANKSHAFT.-One-piece counterbalanced.
MAIN BEARING No.-5
MAIN BEARING TYPE.-White metal
BIG END TYPE.-White metal
LUBRICATION.-Wet sump with automatic replacement of lost oil.
CAMSHAFTS No.-1
CAMSHAFT LOCATION.-Overhead
CAMSHAFT DRIVE.-Shaft and bevel gears
DRIVE LOCATION.-Rear of crank
CLUTCH.-Double cone
GEARBOX LOCATION.-Separate from engine
GEAR RATIOS.-2.7, 4.8, 7.4 and 11.1. (Variations of the top gear available from 2.2 to 2.7.)
TRANSMISSION.-Torque tube drive crown-wheel and pinion for each half-shaft with common differential,
FRAME.-Channel with centre X-brace.
FRONT SUSPENSION.-Semi-elliptic.
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBERS.-Mercedes face cam adjustable.
BRAKE SYSTEM.-Foot ; external contracting on transmission with drum. Diameter 11½ in. x 2-7/8 in. wide. Hand : Rear internal expanding with flexible shoes in drum 13-3/8 in. diameter x 1½ in. wide.
SQ. IN. PER TON LADEN. -172.
STEERING.-Worm and nut. 14 turns lock to lock
WHEELS.-RudgeWhitworth detachable
TYRES.-Continental. Front 820 x 120
Rear 895 x 135

RACING RECORD 1914 G.P. MERCEDES

Date	*Event*	*Course*	*Speed*	*Lap Speed*
5/7/14	French G.P.	Lyons	65.5 m.p.h.	69.95 m.p.h.
30/5/15	500 Miles Sweepstake . .	Indianapolis	89.94 m.p.h.	98.6 m.p.h.
17/7/16	50 Miles Race . .	Omaha	103.45 m.p.h.	—
2/4/22	Targa Florio . . .	Madonie	39.2 m.p.h.	—

EXAMPLE No. SIX

The 1920 Ballot

THE genesis of the eight-cylinder in-line 5-litre racing cars, designed by Henri, for Ballot, in 1919, is described elsewhere, as is the performance of these cars at Indianapolis and in the Targa Florio of that year.

In 1920 the organisers of the 500 Miles Sweepstake at Indianapolis put a limit of 3 litres on engine capacity, and the Ballot brothers decided to compete with three cars which were virtually scaled-down versions of the 5-litre models from the hand of the same designer. All three cars finished (second, fifth and seventh), and R. de Palma was only deprived of victory by misfortune after having put up easily the fastest lap.

In 1921 a similar car was entered with front brakes added and led for the first three hours. In the French Grand Prix the design finished second.

The best lap returned at Indianapolis was 100.75 m.p.h. in 1921, but in 1925 one of these cars put in a lap at Brooklands at 109.22 m.p.h. and a standing lap at 88.10 m.p.h. We may, therefore, have a little hesitation in putting the maximum speed of the car at 110-112 m.p.h.

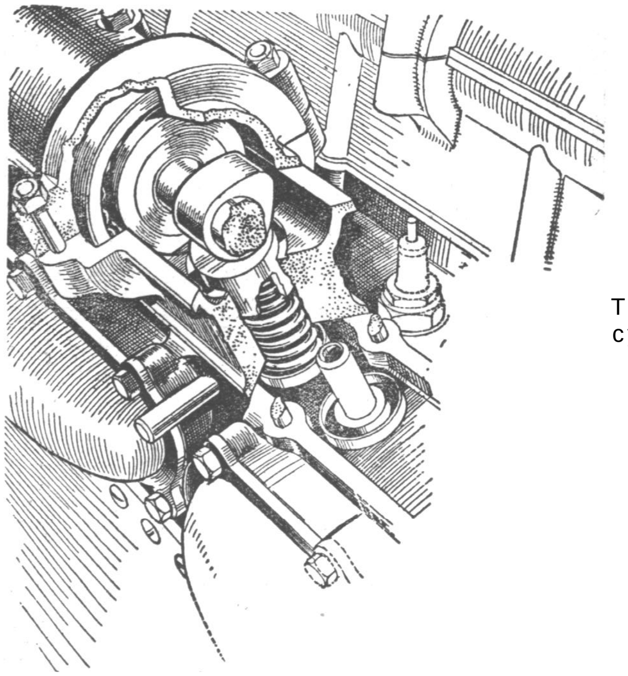
As with the 5-litre model the Ballot showed many traces of Peugeot ancestry. Taking, firstly, chassis features, the drawing shows how Henri retained an engine and gearbox mounted in a sub-frame having a three-point mounting within the main side members, whilst the details of axles and brake, gear steering system are remarkably similar to those employed on the 1914 4½-litre Peugeots. In the brake mechanism, however, one major change was made in that the car was designed to employ a Birkigt type servo motor. This design was originally employed on the 1919 Hispana Suiza and was used by Henri under licence. It consisted of a disc-type brake, driven at slow speeds from a skew gear off the transmission ; the action of the pedal brought a stationary drum into contact with the rotating disc and the turning moment so generated was used to apply both front and rear brakes through a link motion. The result was a very much lighter pedal action than usual.

R. de Pahna, the first driver in the Ballot team, disliked this lightness and refused to have the servo, coupling the pedal to the rear drums and the hand lever to the front axle. It is this system which was present on the car inspected for this chapter, and hence disclosed in the drawings. The motion for the front wheels was carried through an ingenious rack-and-pinion device, and a pivoted cam was used to expand two shoes in the brake drum. The front drums were smaller than the rear, but, even so, the front axle and springs were severely stressed if the brakes were applied hard. In fact, in these circumstances, the king-pin visibly rotates axially and winds up the axle.

The transmission brake used on all racing cars up to this time disappeared, but the general design of transmission remained of conventional form-a Ferodo-lined cone clutch and a separate gearbox with exceedingly close ratios, as can be seen from the data chart. Hotchkiss drive was employed ; both front and rear springs being heavily damped with double Hartford shock absorbers.

The steering and control on this car were notably good, but that was due in part to the very rigid mounting of the steering box on a cross tube. On the other hand, as a consequence of using the sub-frame the engine contributed nothing towards frame

stiffness, and with the extremely exiguous front cross members the fore part of the car was definitely " floppy." The engine was notable for the deliberate choice of a large stroke/bore ratio (1.73:1) in accordance with Henri's known theories on this subject,



The camshaft bears on a steel cylinder fitted over the valve springs

and despite the use of small cylinders both piston speed and maximum r.p.m. were held to very moderate figures. The limit on speed appears to be due to the rather poor design of the big end, which was, nevertheless, a beautiful piece of workmanship. Between the rod and the crankpin was a bronze bush made in two halves, dovetailed together and a close but running fit in the big end. This bush was white-metalled internally to face upon the crankpin, but the motion between its external face and the connecting rod was between the bronze and unhardened steel.

Light-alloy pistons were used. The crankshaft was built up in four sections, three of which were interchangeable. The parts were joined together by taper and key, and the scheme assisted the installation of the main bearings and made for easy replacements if needed.

Lubrication was by the normal Henri principle of a plunger pump scavenging oil from the crankcase, delivering it under pressure to a remote tank and then pumping it back to the main bearings.

The latter consisted of five Hoffman 90 x 123 mm. roller bearings fitted to the 42 mm. diameter crankpin journals. The main bearings were pressed into annular rings having an overall diameter slightly greater than the extreme radius of the crankshaft. The bearings were placed on to the pins in the crank assembly and then fed with bearings into the barrel type crankcase from the rear. Connecting rods were then fitted from above the big end, bolts being inverted so that the nuts could be tightened through inspection holes on the side of the crankcase. The main bearings were fed with oil by means of jets, catcher rings being placed on the webs so as to feed oil in the big ends.

The valve gear was evidently laid out with a view to high r.p.m. and has low inertia. An inverted steel piston fits over the valve springs and a cam bears on its upper

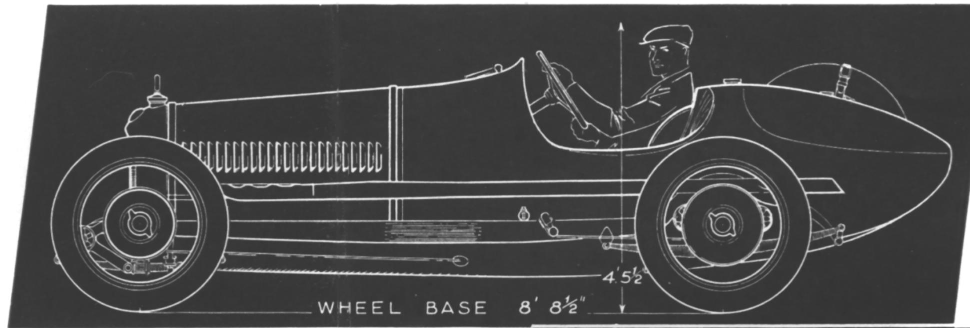
PLATE XIX

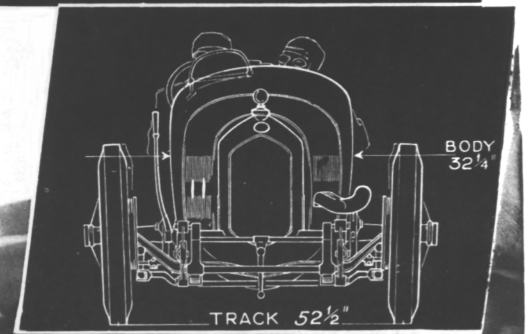
EXAMPLE No. SIX

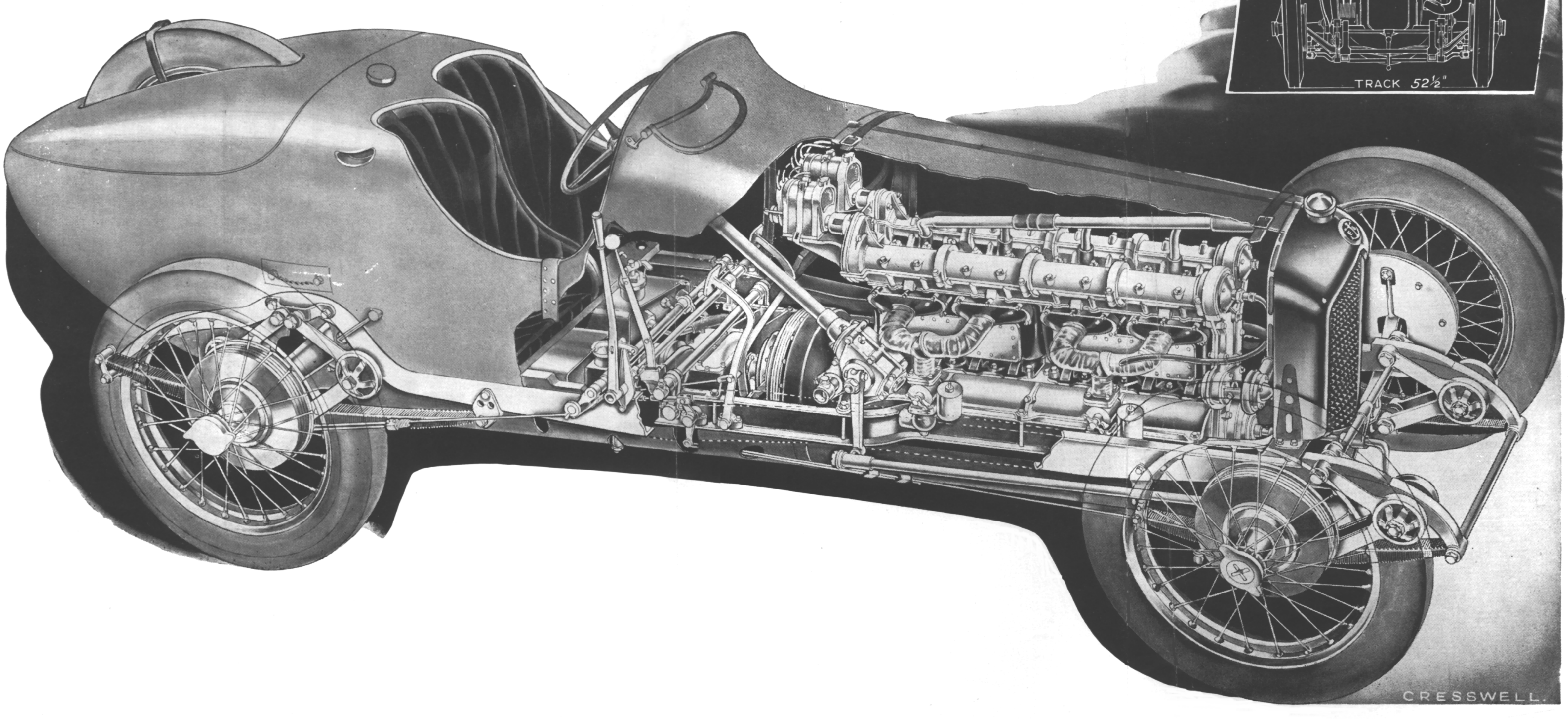
THE 1920 BALLOT

In 1919 the ex-Peugeot engineer, Henri, designed the 4.9-litre Ballot which was the first successful racing car with an eight-cylinder in-line engine. The following year he was responsible for this 3-litre straight-eight Ballot, which developed some 110 b.h.p. at 3,800 r.p.m. The whole design is obviously reminiscent of previous Peugeot practice, and although the crankshaft speed was considerably raised the piston speed was almost unchanged as a consequence of using eight small, in place of four large, cylinders. This car also was one of the first racing engines to use pistons cast in light alloy, and although four valves per cylinder inclined at 60 degrees were retained, the entire valve gear was now enclosed. The lubrication system, transmission and chassis design were directly inherited from 1913 Peugeot design and the front brake mechanism and body shape from the Peugeots built for the 1914 Grand Prix. The brakes were made under Isotta-Fraschini licence with floating front cams and fixed brake cross shafts. The long-tailed, barrel-shaped body contained one spare wheel mounted in the tail.

The improvement in performance compared with the 1913 four-cylinder car designed by the same man may be seen by comparing the speeds at Indianapolis where, for 200 miles in 1920, the eight-cylinder averaged 93.06 m.p.h. In 1921 the car averaged 93.66 m.p.h. for the first 200 miles at Indianapolis, was second in the French Grand Prix at Le Mans and first in the Italian Grand Prix at Brescia.







face. Two camshafts were used, each running in ballbearings, and driven from a train of gears at the front end of the crankcase. Four valves (inlet larger than exhaust) per cylinder inclined at 60 degrees were employed, and this angle was doubtless dictated by the fact that the cylinder head was non-detachable, the cylinders themselves being iron castings made in two blocks of four. Each block had a separate inlet manifold, with a Claude1 carburetter. On the left-hand side of the engine was a straightforward eight-branch outside exhaust.

K.L.G. plugs were used, these being in the centres of the cylinders and the firing order was 1-8-3-6-4-5-2-7.

The camshaft and auxiliary drives were almost replicas of those employed on the 3-litre Peugeot designed seven years previously, except that a short auxiliary shaft driven from the train of gears was used on the Ballot solely to drive a water pump having an out-flow to the exhaust side of the cylinder blocks. By reason of having eight cylinders the designer used two four-cylinder magnetos mounted on the platform attached to the valve housing and driven at engine speed from the rear of the camshafts.

The overall performance of the Ballot was much improved by the body design. This embraced a well-streamlined tail in which the spare wheel was longitudinally mounted and exceptionally low frontal area, the body being remarkably narrow for a two-seater. As shown in a drawing the seats were very much staggered in relation one to the other, the mechanic sitting sideways on and passing one arm behind the driver's seat. The underneath of the car was completely enclosed by an under tray, and although the axles were fully exposed there can be little doubt that the wind resistance of the car was considerably reduced compared to existing practice. Bearing in mind that it was originally designed in 1920, this car may indeed be considered a pioneer in many directions for it combined the multi-cylinder engine with limited engine capacity and a well-formed body. In the year of its original construction it was undoubtedly the fastest car of its type in the world.

Acknowledgments.-The car described and drawn in this chapter was put at the disposal of the artist and author by A. S. Heal, Esq. Further information has been received from M. C. Crowley Milling, Esq., who was the owner of the car in 1947.

DETAILS OF CAR

MAKE.-Ballot
TYPE.-3-litre G.P.
YEAR OF CONSTRUCTION.-1920
YEARS RACED.-1920-21
DESIGNER.-Henri
WHEELBASE.-8 ft. 8½ in.
TRACK FRONT.-4 ft. 4½ in.
TRACK REAR.-4 ft. 4½ in.
HEIGHT TO SCUTTLE.-49 in.
HEIGHT TO DRIVER'S HEAD.-53½ in.
FRONTAL AREA.-12 sq. ft.
UNLADEN WEIGHT.-18 cwt.
ALL-UP STARTING LINE WEIGHT.-23 cwt.
MAXIMUM SPEED.-112 m.p.h. at 3,550 r.p.m.
SPEED ON INDIRECT GEARS.-78 m.p.h. on Third
„ „ „ „ 60 m.p.h. on Second
„ „ „ „ 30 m.p.h. on First at 3,800 r.p.m.
H.P. PER SQ. FT.-9
H.P. PER TON UNLADEN.-119
H.P. PER TON ALL-UP.-93
BORE.-65 mm.
STROKE.-112 mm.
S./B. RATIO.-1.72:1
No. OF CYLINDERS.-Eight
CAPACITY.-2,960 c.c.
PISTON AREA.-41 sq. in.
H.P.-107 at 3,800 r.p.m.
B.M.E.P.-122 lb.
H.P. PER SQ. IN.-2.61
PISTON SPEED FT./MIN.-2,800
CYLINDER HEAD.-Cast-iron integral with block
VALVES No.-Four
VALVES ANGLE.-60 degrees
VALVE AREA INLET.-22.5 sq. in.
VALVE AREA EXHAUST.-18.6 sq. in.
CYLINDER BLOCK.-Iron castings in two blocks of four
FUEL.-Petrol
CARBURETTER.-Two Claudels
SUPERCHARGER.-Nil
MANIFOLD PRESSURE.-Atm.
IGNITION.-2 Marelli magnetos
PLUGS No.-Eight
PLUGS LOCATION.-Vertical in head
CRANKCASE.-Barrel type
CRANKSHAFT.-Five piece built up
MAIN BEARING No.-5
MAIN BEARING TYPE.-Roller
BIG END TYPE.-White metal on bronze floating bush
LUBRICATION.-Dry sump, centrifugal pressure to big ends
CAMSHAFTS No.-Two
CAMSHAFT LOCATION.-Overhead
CAMSHAFT DRIVE.-Train of gears
DRIVE LOCATION.-Front of crank
CLUTCH.-cone
GEARBOX LOCATION.-Separate from engine
GEAR RATIOS.-3.0, 4.2, 5.4, and 11.1
TRANSMISSION.-open propeller shaft to bevel drive rear axle
FRAME.-Channel with U section sub-frame for engine and gearbox mounting
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBERS.-Hartford friction
BRAKE SYSTEM.-Foot : to all four drums through Birkigt type servo ; alternatively, pedal to rear, hand to front drums. Front drum diameter 14 in., rear 15 in.
SQ. IN. PER TON LADEN.-320
STEERING.-Worm and wheel. 1) turns lock to lock.
WHEELS.-Rudge-Whitworth detachable
TYRES.-Front 820 x 120
Rear 835 x 135

RACING RECORD 3-LITRE, EIGHT-CYLINDER BALLOT

Date	*Event*	*Course*	*Speed*	*Lap Speed*
30/5/20	500 Miles Sweepstake . .	Indianapolis	87.47 m.p.h. (second)	99.15 m.p.h.
30/5/21	500 Miles Sweepstake . .	Indianapolis	—	100.75 m.p.h.
26/7/21	French G.P.	Le Mans	73.6 m.p.h. (second)	—
4/9/21	Brescia G.P.	Brescia	90.4 m.p.h.	93 m.p.h.

EXAMPLE No. SEVEN

The 1922 Vauxhall

VAUXHALL Motors, Ltd. ran teams of cars in the 1912 and 1914 Grand Prix races, but following the resignation, in 1919, of Mr. L. H. Pomeroy, their technical director, they abstained from international racing in 1920 and 1921. The latter year, however, they decided to return to the field with an entry of three cars of 3-litre capacity for the 1922 Tourist Trophy races, organised by the Royal Automobile Club and run in June over the traditional Isle of Man circuit. Further entries in other events were planned in ignorance of the fact that the approved international formula for the years 1922-25 embodied a capacity limit of 2 litres. For this reason the cars were debarred from further international competition and restricted to appearances at Brooklands and various national races.

The cars were, moreover, unfortunate in the T.T. race, one being put out by a broken roller on a big-end bearing and another by a piece of metal breaking away from the light alloy piston skirt and jamming between the connecting rod and the crank cheek. Later in the year at Brooklands, the Vauxhall easily beat the Sunbeam car, which had won the T.T. and lapped at 108 m.p.h. (standing lap 93.69), whereas the best lap put up by a 3-litre Sunbeam was 102.9 m.p.h.

In 1925 this model broke the Class D standing kilometre record at 69.75 m.p.h. and the mile at 78.69 m.p.h., and covered the flying kilometre at an average of 111.85 m.p.h.

From these figures we can deduce that the speed between the end of the standing kilometre and the end of the standing mile was at an average of 99.8 m.p.h. and that the maximum speed was of the order of 112 m.p.h.

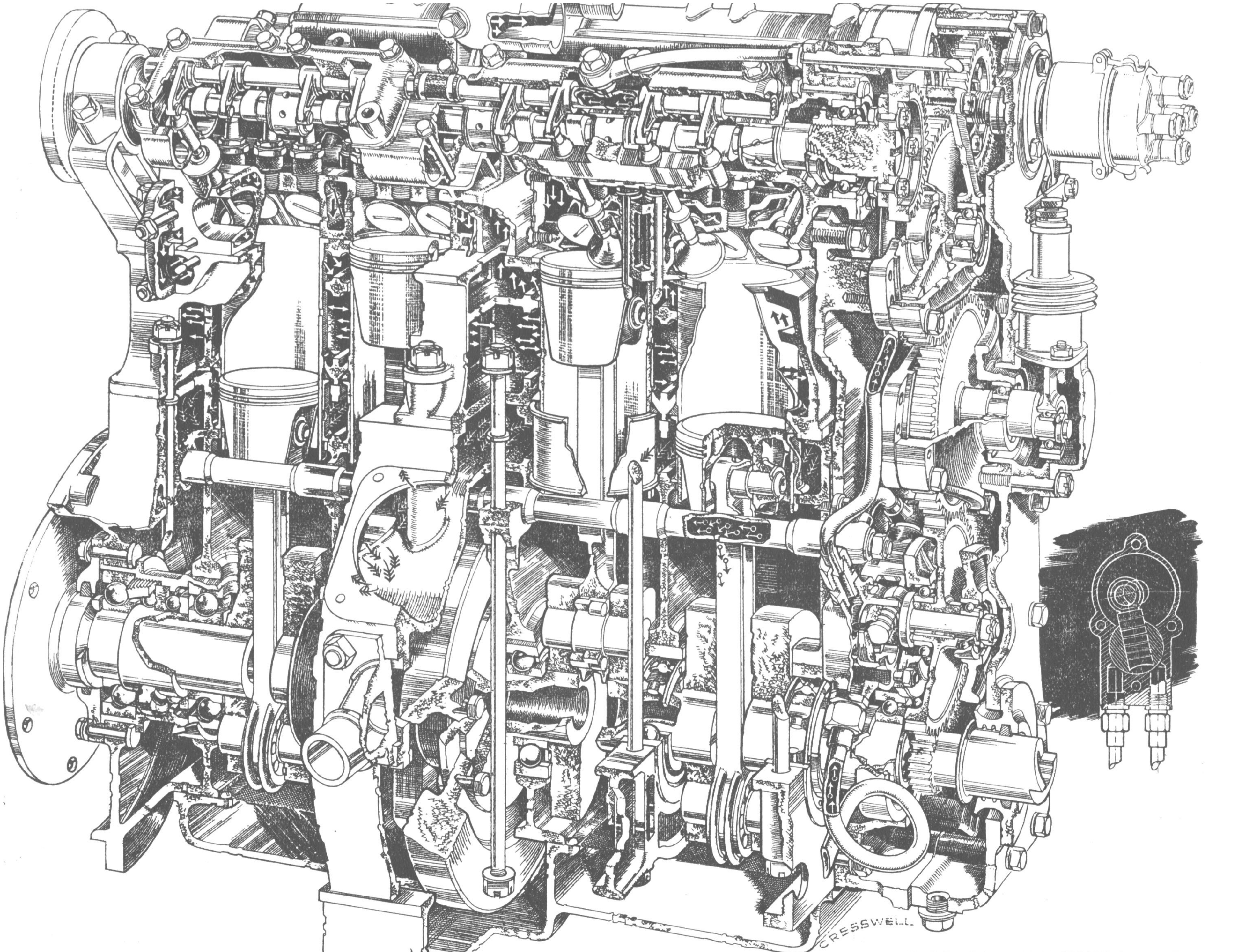
It will be seen that the performance of the cars was highly creditable, so much so that they might well have been serious contenders for Grand Prix honours if they had been constructed twelve months previously.

Two designers were employed, Dr. H. R. (now Sir Harry) Ricardo being responsible as a consultant for the engine design, and the chassis being the responsibility of Mr. C. E. King, who had succeeded to the position of chief engineer.

The chassis was in many ways typical of Vauxhall design of the time ; the rather narrow section frame, front axle beam, method of locking the springs, all bore the traditional hallmark. The use of a frame upswept at the front as well as the back was, however, distinctly novel, as was the unit construction of the clutch and gearbox. The multi-disc clutch and the internals of the gearbox were similar to the components used on the standard production cars, as were such minor items as the steering wheel, pedals and levers, all of which showed clearly their origin.

The ratios in the gearbox were, however, a good deal closer than those obtaining on the contemporary catalogue types, and the final drive was by straight-toothed bevels, giving a 3.75 to 1 ratio and a road speed of 25 m.p.h. per 1,000 r.p.m.

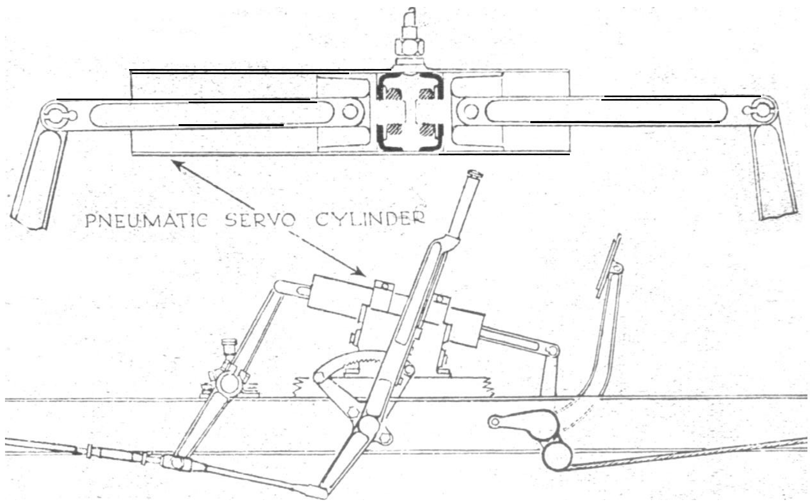
The transmission was unusual in that a disc-type universal was fitted behind the gearbox and a pot-type ahead of the rear axle. Hotchkiss drive was used and a novel feature of the rear axle was the elimination of the differential gear. This was done, in



INTAKE OIL STAGNANT WATER CIRCULATING WATER

part, to reduce unsprung weight ; in part, because it was thought the drive to both wheels would improve adhesion and controllability.

A number of Vauxhall cars had been built in this fashion between 1914 and 1918 and used by various directors of the company, so the step was not made without a good deal of experience to back it up. In practice, it was found that the use of a differential-less axle on a car of this size and weight resulted in a markedly increased tendency to slide on corners, but also gave an excellent measure of control.



The T.T. Vauxhall employed compressed air to operate four-wheel brakes. The pedal and hand systems were independent as far as the driver was concerned, the former connecting to front,and the latter to rear wheel, or operating both simultaneously was a system of cylinders, pistons and rods put into motion by movement of a lever at the top of the steering column.

From the chassis viewpoint, the leading feature of the car was without doubt the fitting of an air-pressure servo device to operate the four-wheel brakes. As this arrangement has never been repeated, it is worth describing in detail. Braking on the 12 in. diameter front drums was by a conventional Perrot lever system; the brake arms being connected directly to the pedal by cables. As originally laid out, a system of rods was used to pull the brake levers backwards, thus giving a servo effect as the front axle rocked over on the springs under the influence of brake torque, but this evidently caused trouble, for when the cars appeared for the race the rods had been partly replaced by cables and the leverage inverted so that at the last stage the motion was reversed and an anti-servo action obtained. On the back wheels, considerably larger drums-16 in. internal diameter-were employed, and the shoes in these were expanded by the long hand brake.

In the centre of the steering column was a small lever which could control the entry of compressed air into a cylinder containing two pistons. One of these pistons, as shown in the drawing, was connected to the front brake system, the other to the rear. As they were of the same diameter, a perfectly even balance of force was applied to the brake rods. More important, very powerful braking could be obtained entirely without muscular effort on the part of the driver. This unique system also made it possible for the brakes to be left on whilst the driver was using his hands and

feet to go through the motion of selecting a lower gear ratio as the car was coming down to a corner ; so although the use of the pneumatic servo involved good judgment, in certain circumstances it could prove of considerable value. Air pressure was provided by a small pump driven off the front timing case of the engine.

A distinctly daring step for a British racing car of 1922 design was the decision to use battery and coil ignition. Delco equipment was fitted, but unlike the contemporary Duesenberg, which is one of the few racing cars ever to use a dynamo, the Vauxhall relied solely on a 12-volt accumulator. This was mounted between the legs of the driver and mechanic, standing immediately on top of the clutch and gearbox housing. In order to obtain greater clarity this component has been eliminated from the cut-away drawing.

The stark but practical appearance of the car has always won the admiration of those who have seen it in pictures or in action. The radiator was set well back from the wheel centres, and the bonnet line was exceedingly low, only just clearing the top of the timing gears and valve covers. As can be seen from the drawing which accompanies this chapter, two large conical wind funnels gave protection to the driver and mechanic, and the former had, in addition, a small windscreen. As run in the T.T. race this screen was provided with a wiper operated manually by the mechanic, and some rudimentary front mudguards were also employed.

The body was of the utmost simplicity, formed, aft the scuttle, by two shallow side members and a large triangular fuel tank containing thirty gallons. On to the back of this were mounted two spare wheels. Air pressure from a hand-pump, worked by the mechanic, supplied fuel to the carburetter.

An interesting feature, originated on the 1914 models, and used on these cars, was the detachable scuttle. This was held down by clips and the regulation strap, as was the bonnet. The scuttle, however, was in one piece, and, by lifting it off, the whole of the centre section of the frame containing clutch, gearbox, instruments, and so on, was left free for inspection.

It will be observed that nothing in the way of streamlining was attempted. This may seem somewhat surprising in view of the fact that Vauxhalls were the first to use a really streamlined body at Brooklands, and owed much of their success on this track to this form.

The drag effect on the speed of the 3-litre car can be seen from the fact that after a long-tail body had been fitted in 1927, the lap speed rose to 116.09 m.p.h., over four miles an hour faster than the best recorded speed over the kilometre (achieved during 1925) with the two-seater body.

The 3-litre engine can fairly claim to be one of the most remarkable power units of all time. It was not, in the light of later development, outstanding on the basis of h.p. per litre, for there are many unsupercharged engines which have exceeded by 50 per cent or more the 43 b.h.p. per litre obtained in this design.

But power-per-litre is a poor basis of comparison and the output measured in relation to piston area is a far more solid ground of comparison. In this regard the Vauxhall engine developed 3.7 h.p. per sq. in. unsupercharged.

Another aspect of the same basic excellence is the 129 b.m.e.p. realised on the Vauxhall at 4,000 ft. per minute piston speed, whilst at the more normally accepted

piston speed, of *circa* 3,500 ft. per minute, the b.m.e.p. was even higher, viz. 139 lb. per sq. in.

The facts regarding this engine are all the more remarkable when one investigates the details of its layout. It was the first multi-cylinder racing engine tackled by its now eminent designer ; the compression ratio and valve timing were moderate, and no tricks of " tuning " were employed.

In analysing the features contributing to the success of the engine, one immediately realises that it is based on unusually good values for volumetric and mechanical efficiency. The importance of the former is generally realised, and most racing car designers have spent a great deal of time securing the best possible filling of the cylinders. The Vauxhall volumetric efficiency exceeded 80 per cent in the speed range 2,700 and 3,800 r.p.m., and held up to 77 per cent at 4,500 r.p.m. The valve gear embodied two inlet and two exhaust valves per cylinder with an included angle of 90 degrees. The inlet ports were 1.34 in. diameter and the exhaust 1.3 in. diameter, and the lift of both was the same, viz., 9 mm. The inlet valves were masked for the first 0.05 in. of travel ; that is to say, the valve head was set back into the cylinder by this amount, and at the point of opening the cam has already given it considerable acceleration.

In order to make possible comparisons with other engines described in this book where the overall diameter of the valve head has been taken as a criterion, it should be put on record that the sizes are 1.45 and 1.38 respectively, and it is these figures which have been used in the table of statistics,

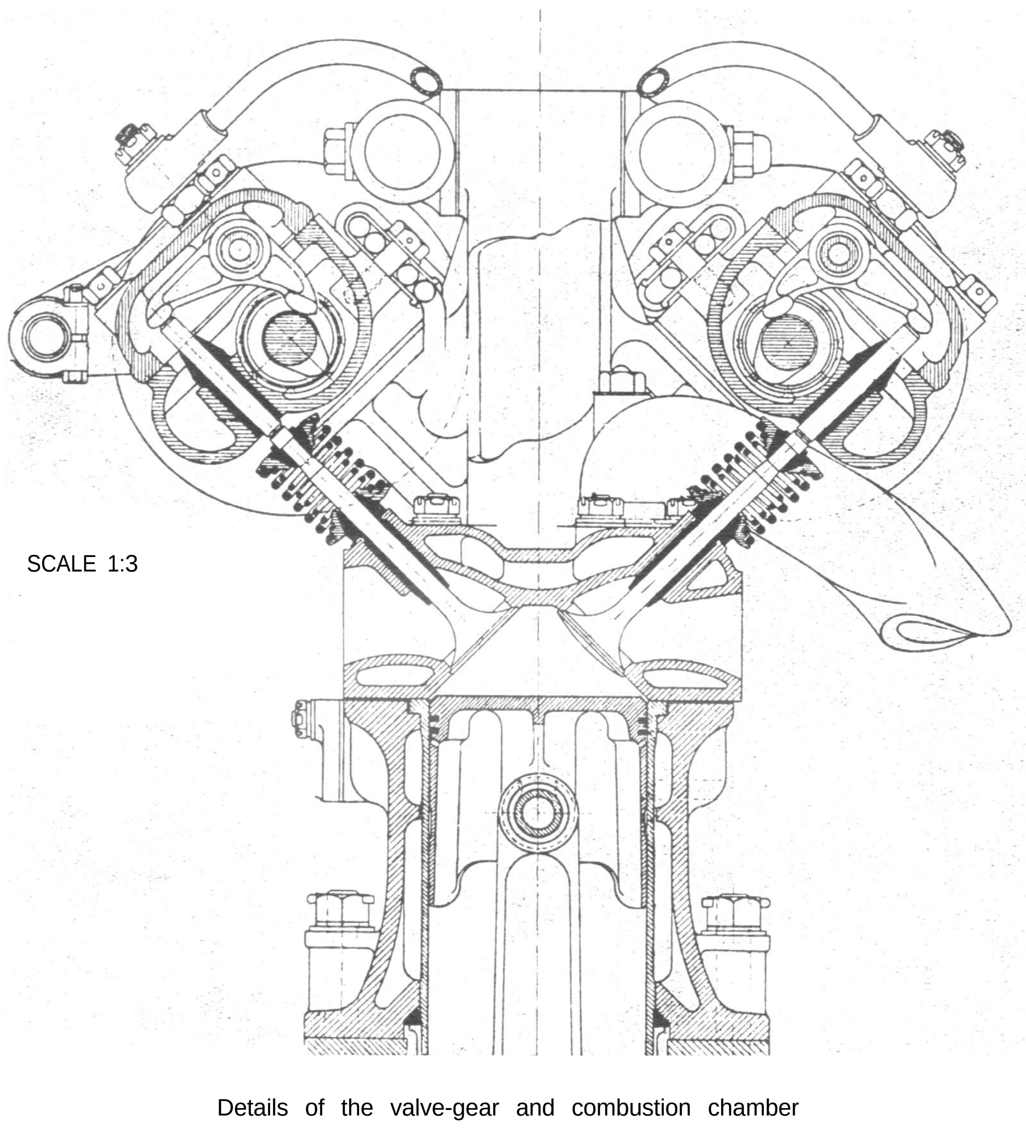
The use of rockers and short, non-adjustable tappets in the valve gear is clearly shown in the drawing, and needs no comment except that low-lift cams were used with moderate acceleration and very lightly stressed valve springs. The induction system was of distinct interest, as the twin-choke-type Zenith carburetter induced air across the crankcase, and the manifolding to cylinders Nos. 2 and 3, and 1 and 4 was entirely separate with no overlapping impulses to upset the distribution.

Ignition was by central sparking plug, there being, however, provision for an extra plug on each side. No advantage was derived from this arrangement, and consequently it was not used. Equal care, from a volumetric point of view, was given to the exhaust side of the engine, and Dr. Ricardo was one of the first to appreciate that each valve should have its own duct and pipe.

The cooling of the exhaust valves can be commended. Not only was there a reasonable amount of water around the entire circumference of the valve guide ; there was also a good water space around the base of the valve seat. The material used for the cylinder head was hard bronze, and no inserts for valve seats, either inlet or exhaust, were fitted or found subsequently to be necessary. There were actually two detachable heads, each containing two combustion spaces, and water was delivered direct to the exhaust side of each head from the pump through a " Y " branch manifold.

The circulation system was of distinct interest, for there was no direct connection between the head and the cylinder block. After the cold water had been delivered to the hottest part of the engine it was transferred through two external pipes to the top section only of the cylinder block. A long, vertical riser pipe was placed between the two cylinder heads, and water escaped from the top of the block up this pipe and thence back to the radiator. The lower part of the block was sealed off and contained stagnant water only.

When the engine was designed it was expected to obtain additional cooling from the use of alcohol fuel, and a very high compression ratio had been envisaged. This scheme was abandoned, as it was found difficult to provide an efficient form of combustion chamber whilst simultaneously avoiding the risk of the pistons being struck by the valves should they accidentally stick in full open position.



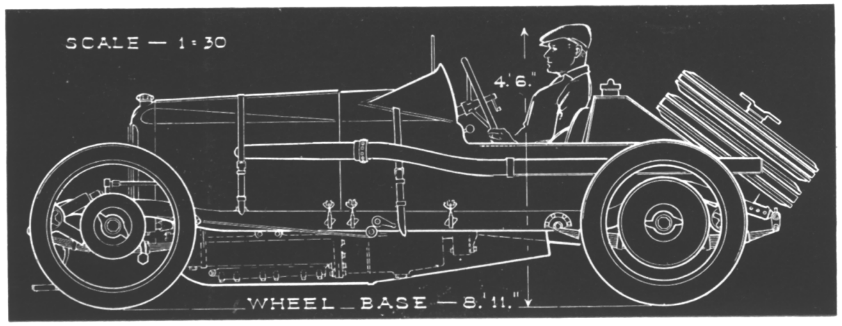
Details of the valve-gear and combustion chamber

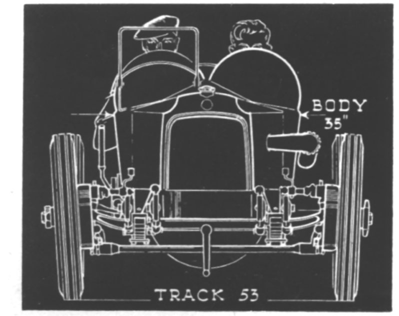
One might consider such thoughts unwarrantable pessimism on the part of a racing-engine designer, but, nevertheless, the compression ratio finally employed was the very moderate one of 5.8 to 1. This latter figure makes the power output of the engine all the more creditable, for a maximum indicated pressure of 162.5 lb. was realised at 3,500 r.p.m. (3,040 f.p.m.), and 159 i.m.e.p. at 4,500 r.p.m. (3,900 f.p.m.). The combustion efficiency at the highest speeds was 34.8 per cent, and at full load at 3,000 r.p.m. the consumption was only 0.45 pints per b.h.p. an hour.

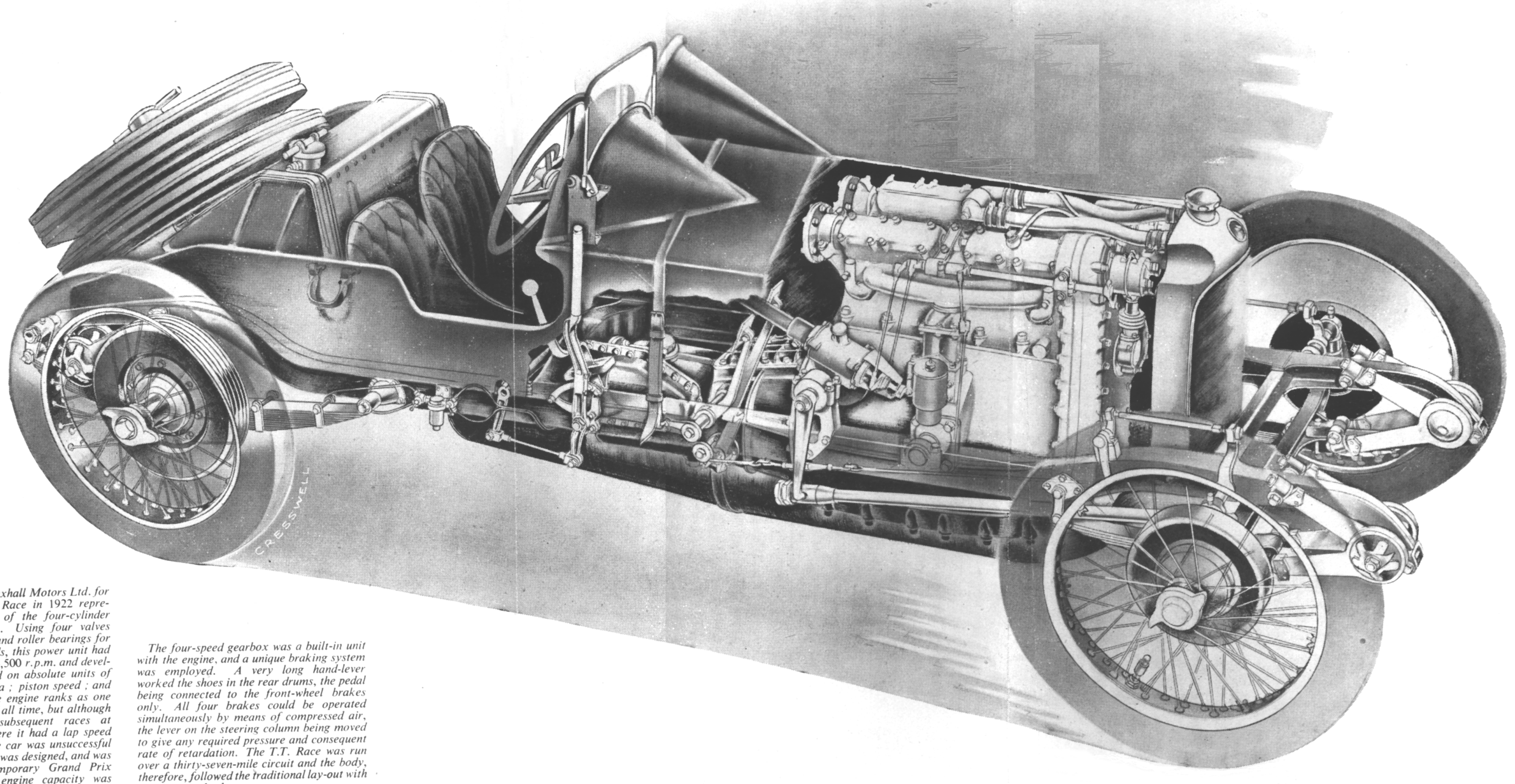
Possibly the most significant feature of this engine, was its phenomenally high mechanical efficiency. At 3,000 r.p.m. the figure is over 80 per cent and at 4,500 r.p.m.

EXAMPLE No. SEVEN

THE 1922 VAUXHALL







The cars built by Vauxhall Motors Ltd. for the Isle of Man T.T. Race in 1922 represented the apotheosis of the four-cylinder unsupercharged engine. Using four valves per cylinder, and ball and roller bearings for crankshaft and big-ends, this power unit had a crankshaft speed of 4,500 r.p.m. and developed 129 b.h.p. Based on absolute units of comparison (piston area ; piston speed ; and manifold pressure), the engine ranks as one of the most efficient of all time, but although performing well in subsequent races at Brooklands Track, where it had a lap speed of over 108 m.p.h., the car was unsuccessful in the race for which it was designed, and was excluded from contemporary Grand Prix events in which the engine capacity was limited to 2 litres.

The four-speed gearbox was a built-in unit with the engine, and a unique braking system was employed. A very long hand-lever worked the shoes in the rear drums, the pedal being connected to the front-wheel brakes only. All four brakes could be operated simultaneously by means of compressed air, the lever on the steering column being moved to give any required pressure and consequent rate of retardation. The T.T. Race was run over a thirty-seven-mile circuit and the body, therefore, followed the traditional lay-out with two spare wheels.

it is 78 per cent. Thus the Vauxhall engine may be considered to gain between 20 and 30 b.h.p. over normal designs solely by reason of abnormal mechanical efficiency.

This gain was earned by exceedingly careful design. In particular by ensuring that the whole engine was remarkably rigid. The crankcase, which was made in two halves, was exceptionally deep, and was joined together by a row of internal nuts along the side walls and also by long through bolts adjacent to the bearings. A shallow detachable sump was fitted at the base. The cylinder block was a light alloy casting of comparatively short length, and the cylinder proper formed from detachable wet liners, deeply spigoted into the crankcase. The top half of the latter was a double cell, which formed an air passage around the base of the cylinder liner. The carburetter drew air across the engine, and, therefore, received it slightly warmed, while the sealing-off of the water around the centre of the liner kept it at a high temperature. These features were deliberately included in order to reduce the viscosity of the oil on the cylinder bore and thereby lower piston friction losses.

The pistons themselves were of the Ricardo slipper type, the non-thrust surfaces being entirely " cut away." Only two piston rings were employed. Having thus done everything possible to reduce the losses in the top half of the engine, Ricardo decided to employ a complete ball and roller bearing layout for the crankshaft and big ends. Other factors influencing this decision were the desire to make the engine as short as possible in order to improve the overall stiffness and to reduce the possibilities of torsional vibration trouble. In order to eliminate the last named it was further decided to place the flywheel in the centre of the engine, and, after a good deal of consideration, a completely built-up crank, made from plain pins on to which the crank throws were shrunk as in gas-engine practice, was incorporated. A solid big end for the connecting rod could thus be provided, the bearing being a double row of short rollers located in a one-piece bronze cage, the outer race being made by hardening the eye of the connecting rod itself. Both crankshaft and connecting rod were made from low carbon case-hardened steel.

Lubrication was provided from two oscillating valveless plunger pumps, one supplying the oil to a gallery running the full length of the crankcase and provided with jets spraying lubricant to the crank throws, the other working at some 25 lb. per sq. in. and delivering oil to the valve rockers.

These pumps, together with a large-capacity air pump connected to the brake servo mechanism, and a smaller-capacity pump maintaining the pressure in the fuel tank, were driven from a train of spur gears fixed at the front end of the engine to drive the two camshafts. An elaborate system of spiders was employed in order to provide accurate meshing of the gears, there being no fewer than seven wheels in the complete train. This meshing had, of course, to be individually carried out, and the spiders were then fixed by a dowel pin in the correct position. A description of this item does, however, bring one to the point of criticism, which is this : although the scientific basis of the engine was of first-rate quality, the mechanical realisation of the principles involved resulted in an exceedingly complicated layout for a four-cylinder engine built in very small quantities.

The timing wheels are one case in point, others being the machining difficulties involved in aligning the holes for the long through bolts, whilst, as the cut-away drawing shows, there are a number of other points where the workshop has certainly been

subordinate to the drawing office. Whether or not this caused such delays in construction as to reduce the time available for final tuning, and impaired the chances of the cars in the T.T. race, is a debatable point. Actually one engine was completed well ahead of time and ran on the bench the equivalent of over 4,000 miles on the road before the event. Nevertheless, a general lesson of racing-car design is that the layout must be appropriate to the resources and cash of the manufacturer, and it is by keeping this in mind that such constructors as Bugatti and Alfa Romeo scored their consistent victories over a long period of years.

Acknowledgments.-Thanks are due to Vauxhall Motors, Ltd., Anthony Brooke, Esq., and Messrs. Molyneux and West for assistance in obtaining data and drawings on this example.

DETAILS OF CAR

MAKE.-Vauxhall
TYPE.-T.T.
YEAR OF CONSTRUCTION.-1922
YEARS RACED.-1922-23 by Manufacturers
DESIGNERS.-King and Ricardo
WHEELBASE.-8 ft. 11 in.
TRACK FRONT.-4 ft. 5 in.
TRACK REAR.-4 ft. 5 in.
HEIGHT TO SCUTTLE.-47 in.
HEIGHT TO DRIVER'S HEAD.-54 in.
FRONTAL AREA.-14 sq. ft.
UNLADEN WEIGHT.-22.5 cwt.
ALL-UP STARTING LINE WEIGHT.-27 cwt.
MAXIMUM SPEED.-112 m.p.h. at 4,400 r.p.m.
SPEED ON INDIRECT GEARS.-98 m.p.h. on Third
„ „ „ „ 70 m.p.h. on Second
„ „ „ „ 48 m.p.h. on First at 4,800 r.p.m.
H.P. PER SQ. FT.-9.3
H.P. PER TON UNLADEN.-112
H.P. PER TON ALL-UP.-95.5
BORE.-85 mm.
STROKE.-132 mm.
S./B. RATIO.-1.55:l
No. OF CYLINDERS-Four
CAPACITY.-2,996 c.c.
PISTON AREA.-35.2 sq. in.
B.H.P.-129 at 4,500 r.p.m.
H.P. PER SQ. IN.-3.66
B.M.E.P.-125
PISTON SPEED FT./MIN.-3,900
CYLINDER HEAD.-Bronze, detachable in pairs
VALVES No.-Four per cylinder
VALVES ANGLE.-90 degrees
VALVE AREA.-Inlet 13.3 sq. in.
Exhaust 12 sq. in.
CYLINDER BLOCK.-Aluminium with wet cast-iron liners
FUEL.-Petrol
CARBURETTER.-Double choke Zenith
SUPERCHARGER.-Nil
MANIFOLD PRESSURE.-Atm.
IGNITION.-Delco coil with twin distributors
PLUGS No.-Twelve
PLUGS LOCATION.-In line in centre of head
CRANKCASE.-Light alloy Split on centre line of bearings. Separate sump added to base
CRANKSHAFT.-Built-up with central flywheel. Counterbalanced.
MAIN BEARING No.-Six
MAIN BEARING TYPE-Ball
BIG END TYPE.-Roller
LUBRICATION.-Wet Sump
CAMSHAFT No.-Two
CAMSHAFT LOCATION.-In head
CAMSHAFT DRIVE.-Train of gears
CAMSHAFT DRIVE LOCATION.-Front of engine
CLUTCH.-Multi-plate
GEARBOX LOCATION.-In unit with engine
GEAR RATIOS.-3.75
„ „ 4.65
„ „ 6.5
9.4
TRANSMISSION.-Open propeller shaft to bevel drive rear axle
FRAME.-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBER TYPE.-Hartford friction
BRAKE SYSTEM.-Mechanical with compressed air servo
BRAKE DRUM DIAMETER.-Front 12 in.
Rear 16 in.
BRAKE DRUM WIDTH.-2½ in.
SQ. IN. PER TON LADEN.-320
STEERING.-Worm and wheel. 1½ turns lock to lock
TYRES.-Palmer 810 x 90 front
820 x 120 rear

RACING RECORD 1922 T.T. VAUXHALL

Date	*Event*	*Course*	*Speed*	*Lap Speed*
22/6/22	T.T.	Isle of Man	52.71 m.p.h. (third)	—
-/10/22	3-Litre Championship .	Brooklands	97.8 m.p.h.	108.27 m.p.h.

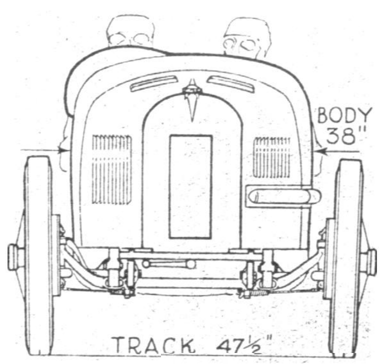
EXAMPLE No. EIGHT

The 1922 FIAT

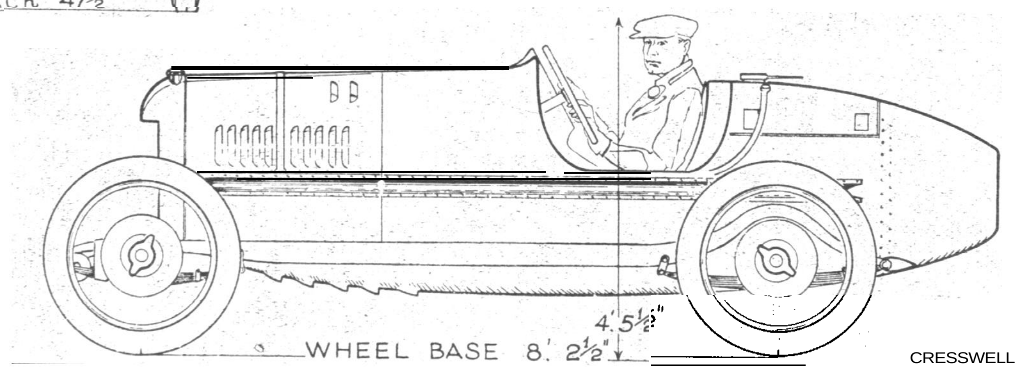
FIAT cars were amongst the leaders in Grand Prix racing before the outbreak of the 1914 war. They were particularly successful between 1905-8 ; they consistently supported racing during the lean years of 1909, ‘10 and ‘11, and might well have won the 1912 Grand Prix, being only removed from the lead by the minor trouble of a broken fuel pipe. The Company abstained from racing in 1913, and although in 1914 the cars they ran at Lyons were of an advanced design, including an overhead cam-shaft and front wheel brakes, they were not successful, only one car finishing and that was last. Immediately after this race the engines were rebuilt with welded-up steel cylinders on the Mercedes model and a team was re-entered for the first post-war European event, the 1919 Targa Florio. Again they were unsuccessful and the type secured its only win when sold to an amateur (Count Masetti), who won the 1921 Targa Florio.

The technical merit of the design had, however, been established and the steel cylinder construction was utilised in the 1921 eight-cylinder Fiats built to the 3-litre formula.

These cars (which had cylinder dimensions 65 x 112 mm.) were notable for pioneering two other detail developments, viz. : the use of valves inclined at an included angle of “ 100 ” degrees in a fixed cylinder head and the conjunction of roller bearing big ends with a one-piece crankshaft. The former feature enabled valves of exceptional



Dimensional drawings of the 1922 FIAT (Scale 1 : 30)



size to be employed and a majority of Continental racing car designers have since chosen “ 100 ” degrees valve angle rather than 90 degrees. The use of roller bearings

for the big ends was no novelty in itself, but the decision to have a one-piece crankshaft and to split the connecting rod big ends was a daring one which by its success has also led to wider acceptance.

The completion of the 3-litre cars was delayed by the labour troubles prominent in post-war Italy and they ran in only one race, the Italian Grand Prix, in which they proved themselves the fastest car of the year. They suffered from mechanical trouble, which prevented them from winning, but the lessons learnt in their construction were embodied in the design of the 2-litre cars constructed for the 1922 Grand Prix, in which they likewise proved themselves by far the fastest cars of their time.

In the French Grand Prix at Strasbourg the relative lap speeds of the three principal contenders were :

Fiat 87.75 m.p.h. (100)

Bugatti 80 m.p.h. (91.5)

Sunbeam 78 m.p.h. (89)

the percentage speeds being put in parentheses. Felice Nazzaro, who drove the winning car, averaged 79.2 m.p.h. for the whole distance of 498 miles, the relative speeds being :

Fiat 79.2 m.p.h. (100)

Bugatti 69.2 m.p.h. (87.5).

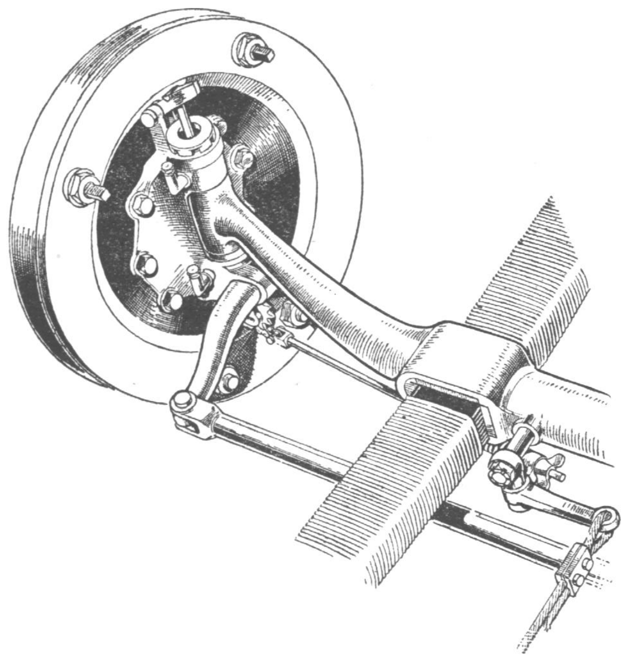
No Sunbeam finished.

This demonstration of superiority was such that in the Italian Grand Prix virtually no opposition was offered and the Fiats had a walk-over.

The disappointment which must have attended the construction of the 3-litre car was, therefore, more than atoned by the racing record of the 2-litre model.

The engineers responsible for this highly-original design (car Type 804 and engine Type 404) were Cavalli, Cappa, Bertarione and Bechia who were under the direction of Fornaca. The whole concept was very closely based on the preceding 3-litre car but the steel cylinder blocks were now welded up in pairs of three instead of pairs of four and the stroke reduced from 112 to 100 mm. As can be seen from the drawings, the crankshaft was heavily counter-weighted and ran in eight roller bearings, 10 mm. diameter and 18.5 mm. long, the diameter of the journals being 40 mm. Oil was fed into the main bearings and on escape was trapped in circular grooves machined in the face of the crank cheeks and was thence fed under centrifugal pressure to the big ends. These also had rollers of 8 mm. diameter and 18 mm. long with the crank pin 14 mm. diameter and, as before mentioned, the rollers ran in split cages which were, in the first instance, bronze and later changed to duralumin.

A feature of the connecting rods was their almost parallel section and great length, viz. stroke x 2.23. Light alloy pistons were employed and it is particularly interesting to know that they were held clear of the cylinder bores by piston rings which were an interference fit on the inside of the ring grooves. This gave a steel-to-steel bearing surface with a correspondingly short life but there was no objection to renewing the rings at the end of every race. It will be observed that two compression and one bottom ring were employed and that the pistons were liberally drilled around a deeply relieved waist.



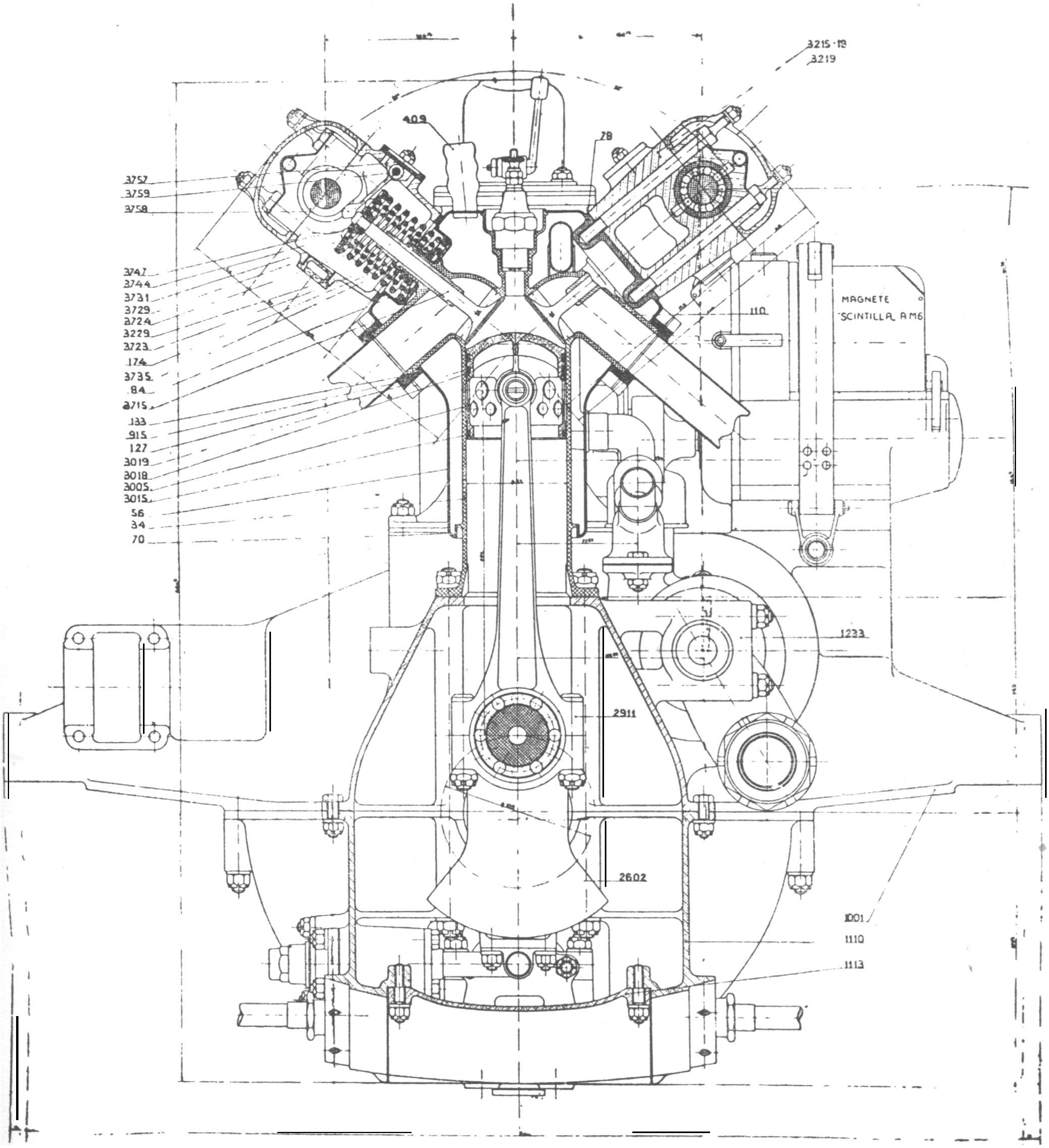
The front axle was tubular and the springs passed through the axle beam.

The full roller bearing crankshaft resulted in a notably short engine measuring only 27½ in. from the nose of the crank case to the face of the clutch housing, but the rather long connecting rods resulted in a great depth between the crank centre line and the valve ports. It will be observed that these made a somewhat sharp angle in relation to the valves and that the sparking plugs were positioned centrally in the head but masked with a hole about 12 mm. diameter. The good cooling of the threaded portion of the plug is a particularly commendable feature of this engine, which was also notable for the use of high velocity water on the exhaust side, a long conduit being placed within the head adjacent to the sparking plug bases and running immediately over the exhaust valve ports and guides.

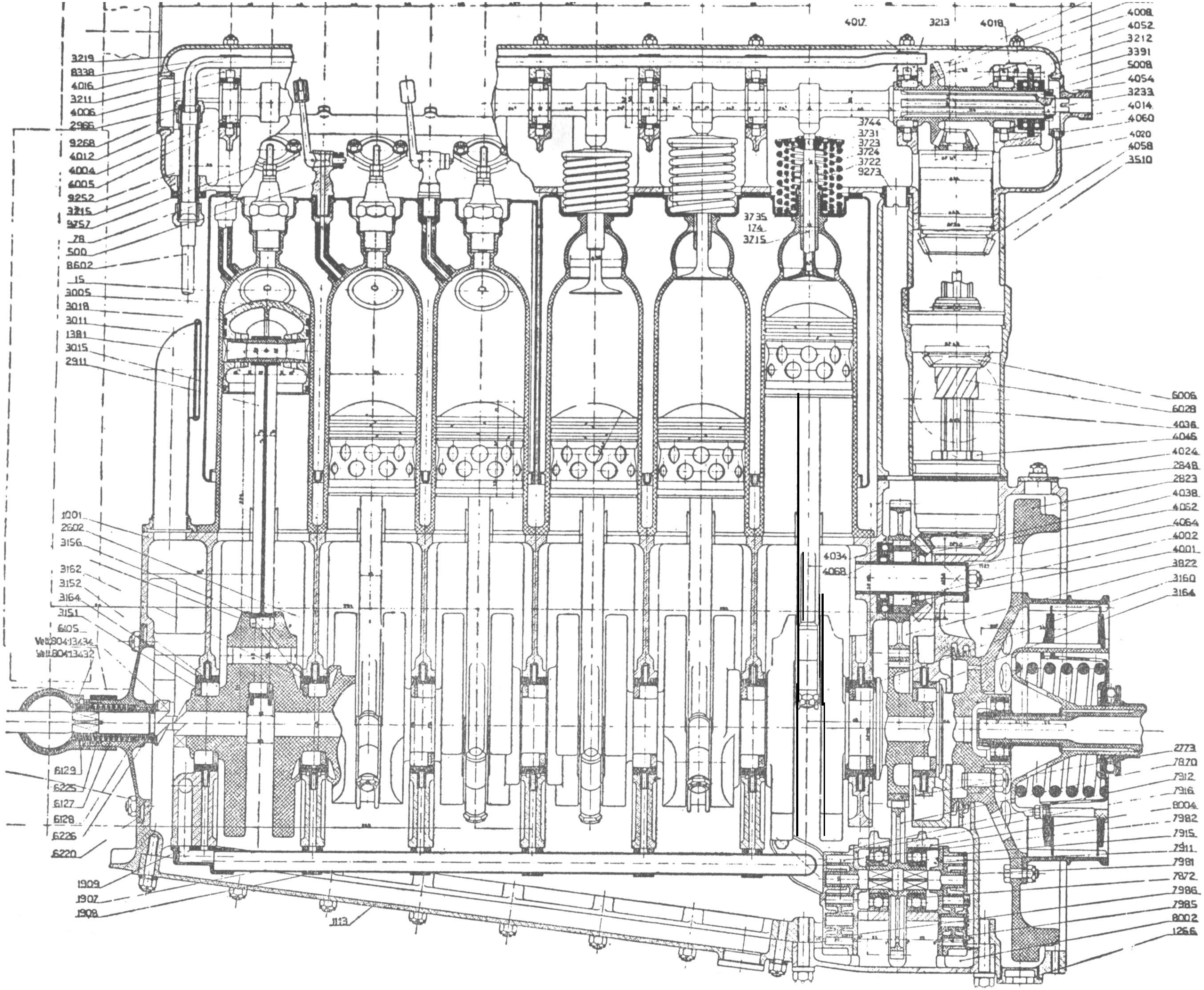
The valves themselves were closed by three large-diameter valve springs and opened by camshafts running in seven roller bearings through the medium of cam followers and owing to the large included angle between the valves the shafts were somewhat widely divided and presented some special problems in the layout of the driving mechanism. From external appearance it might be assumed that trains of gears were employed but in point of fact two spur gears only were used to drive a small sub-shaft at engine speed. This drove a short vertical shaft through the medium of bevel pinions and joined to these were two inclined shafts, each one of which drove a camshaft through the medium of bevel gears, the whole layout thus giving a Y formation.

A skew gear was mounted on the vertical shaft to drive a magneto which faced outwards to the exhaust side of the engine and there was an advance and retard mechanism which ensured maximum spark intensity at all positions exactly as on the 1910 model.

Dry sump lubrication was used, circulation being through an eight-gallon oil tank with a further reserve of eight gallons in a second tank, a pump being provided inside the scuttle so that the mechanic could avoid engine failure in the event of the oil consumption exceeding 50 m.p.g.



This 1 : 4 scale drawing of the 1922 Fiat engine shows the wide valve angle, masked sparking plugs and internal conduit feeding cold water direct on to the exhaust valve port. Other salient features are the use of roller bearings in conjunction with a split big end and the drilled light alloy piston separated from the steel cylinder by bottom seating piston rings.



The side elevation of the 1922 Fiat engine (scale 1 : 4) shows the method of assembling the steel cylinders in two pairs of three, also the three-piece drive to the two overhead camshafts and the skew gear which advanced or retarded the magneto which was driven to a cross shaft connected to the inverted bevel gear part number 6006. The continued use of compression taps is an interesting survival. contrasting strangely with the all roller bearing crankshaft.

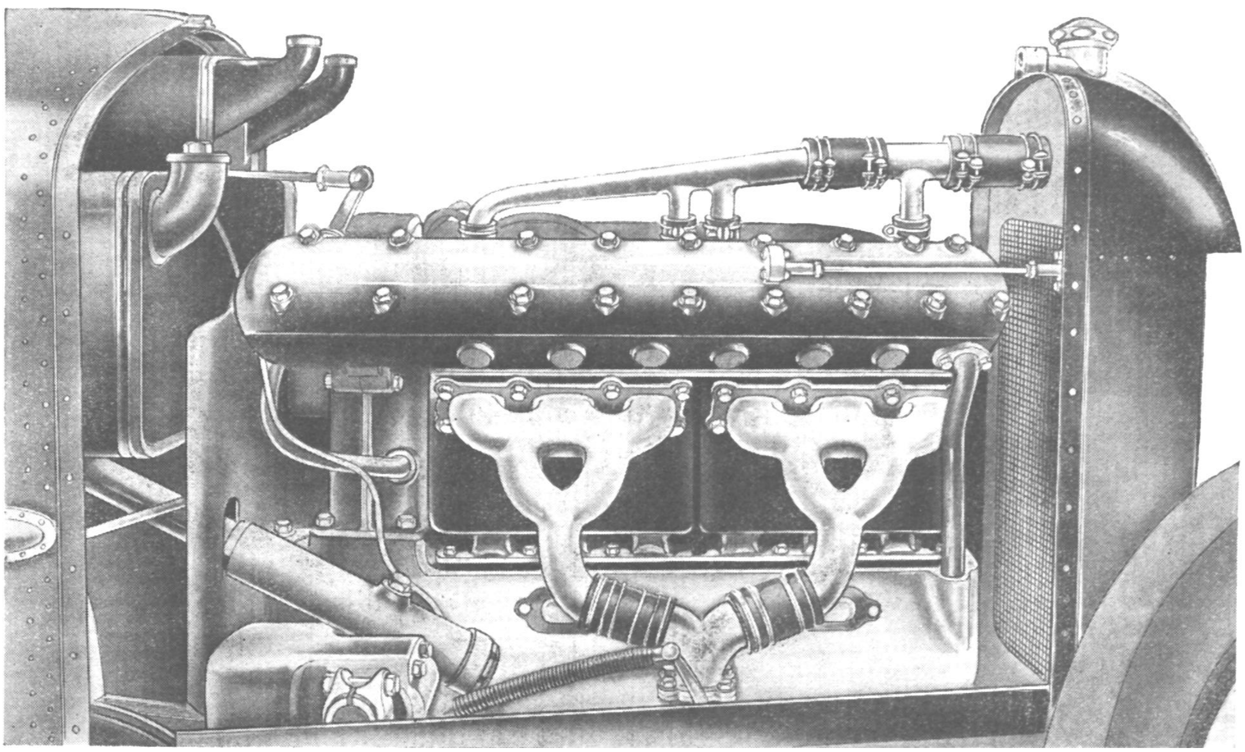
Although developing between 92 and 96 h.p. at 4,500 r.p.m. for the French Grand Prix, for the Italian Grand Prix the output was raised to 112 h.p. at 5,000 r.p.m. with a corresponding figure of 145.5 b.m.e.p.-an extremely creditable figure on a compression ratio of 7 : 1.

The drive was taken through a multi-plate clutch to a four-speed gearbox mounted in unit with the engine, this model and the T.T. Vauxhall being amongst the first to use this construction, which had been initiated, so far as racing was concerned, on the 4½-litre Fiats which ran in the 1914 French Grand Prix. At the back of the gearbox was a housing to receive a sphere which took the drive, the rear axle being of torque tube type suspended on semi-elliptic springs, the latter very short and stiff. The rear axle itself was notable in being made from thin gauge pressings welded together, and in the French Grand Prix it was found that one of the flanges at the wheel end was insufficiently strong and broke away, so that two out of the three cars lost a rear wheel.

The front axle had considerable technical interest. It was now realised that adequate front brakes imposed considerable stresses on the axle beam, and for this reason Fiat engineers fixed upon a tubular front axle, although one of small section. They decided to make it in two pieces joined together on the centre line, and by reason of this arrangement the centre, unstressed, part could be machined hollow. At the centre line it was serrated to prevent relative movement and pinned to avoid separation. The springs were taken through the front axle beam.

The front brakes themselves were operated by means of cables and bell cranks and thence, as is shown in a drawing, to a small chain and a vertical rod which went through the centre of a hollow king pin.

Brake drums were of aluminium with cast-iron liners.



Drawing of Engine, off side

The pedal effort of the driver was reinforced by a servo mechanism, of which no details are available. In principle a pump supplied oil to a piston and cylinder linked to the brake mechanism. It will be noted that the steering box was held on to the crank-case casting, which is a typical Fiat practice.

The dimensions of the car were kept as small as possible, the wheelbase being only 8 ft. 2 in. and the track 47 in. The frame and axles were of very slender proportions and the former was shaped to follow the contour of the two-seater body. Hence the frame members tapered not only towards the front, as was quite common, but were also cranked in at the back to follow the tail lines of the car. Nevertheless, the centre section of the body was comparatively wide and this, in conjunction with a marked stagger of the mechanic's seat in relation to the driver's, enabled the crew to be almost entirely enclosed within the main form of the car.

A large portion of the tail was taken up with a rectangular fuel tank and, as can be seen from a drawing, an under tray enclosed almost the entire bottom half of the vehicle. There can be no doubt that the drag losses on this car were considerably lower than normal. The exceptionally light weight of the complete vehicle was even more remarkable. The 1922 regulations stipulated a minimum weight of 12.7 cwt., and Fiats were weighed in at Strasbourg at approximately 13 cwt., and thus have the distinction of being the lightest cars to win a full Grand Prix race prior to 1939.

The complete superiority of these cars over contemporary 2-litre models, and the impression that they made on technical opinion, can be likened to the effect of the first Mercedes car in 1902 and the 1912-13 Peugeot models designed by Henri. No one was more aware of their significance than Mr. Louis Coatalen, who engaged one of the Fiat racing designers, Signor Bertarione, and charged him with responsibility for constructing the Sunbeam racing cars of 1923-4. The latter are described in Example No. 9 following this chapter, and the reader should appreciate that the cars have many similar features of design.

DETAILS OF CAR

MAKE.-Fiat
TYPE.-1922 G.P.
YEAR OF CONSTRUCTION.-1922
DESIGNERS.-Fornaca, Cappa and Bertarione
WHEELBASE.-8 ft. 2½ in.
TRACK.-Front 3 ft. 11½ in.
Rear 3 ft. 11½ in.
HEIGHT TO SCUTTLE.-50 in.
HEIGHT TO DRIVER'S HEAD.-53½ in.
FRONTAL AREA.-12.2 sq. ft.
UNLADEN WEIGHT.-13 cwt.
ALL-UP STARTING LINE WEIGHT.-18 cwt.
MAXIMUM SPEED.-105 m.p.h.
SPEED ON INDIRECT GEARS.-Unknown
H.P. PER SQ. FT.-7.6
H.P. PER TON UNLADEN.-142
H.P. PER TON ALL-UP.-102
BORE.-65 mm.
STROKE.-100 mm.
S./B. RATIO.-1.54:l
No. OF CYLINDERS.-Six
CAPACITY.- 1,991 c.c.
PISTON AREA.-30.8
B.H.P.-92 at 4,500 r.p.m.
B.M.E.P.-133
H.P. PER SQ. IN.-3.0
PISTON SPEED FT./MIN.-3,420
CYLINDER HEAD.-Steel integral with barrel
VALVES No.-Two per cylinder
VALVES ANGLE.-96 degrees
VALVES AREA INLET.-11.2 sq. in.
VALVES AREA EXHAUST.-11.2 sq. in.
CYLINDER BLOCK.-Steel barrels with welded-up ports and jackets in two blocks of three
FUEL.-Petrol
CARBURETTER.-Single Fiat
SUPERCHARGER.-Nil
MANIFOLD PRESSURE.-Atm.
IGNITION.-One magneto
PLUGS No.-Six
PLUGS LOCATION.-Vertical in head
CRANKCASE.-Light alloy split on centre line of bearings
CRANKSHAFT.-One-piece counterbalanced
MAIN BEARING No.-Eight
MAIN BEARING TYPE.-Roller
BIG END TYPE.-Roller
LUBRICATION.-Dry Sump
CAMSHAFT No.-Two
CAMSHAFT LOCATION.-In head
VALVES OPERATED.-Through fingers
CAMSHAFT DRIVE.-Gear-driven vertical shaft and bevels
CAMSHAFT DRIVE LOCATION.-Rear Of engine
CLUTCH.-Multi-plate
GEARBOX LOCATION.-In unit with engine
GEAR RATIOS.-Unknown, four speeds
TRANSMISSION.-Torque tube to bevel drive rear axle
FRAME.-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBER TYPE.-Hartford friction
BRAKE SYSTEM.-Foot : mechanical with oil pressure servo to all four drums. Hand : rear drums only
BRAKE DRUM DIAMETER.-12.5 in.
BRAKE DRUM WIDTH.-1½ in.
SQ. IN. PER TON LADEN.-250
STEERING.-Worm and nut
TYRES.-Pirelli. Front 31 X 3½
Rear 32 x 4
WHEELS.-Rudge-Whitworth

RACING RECORD, 1922 GRAND PRIX FIAT

Date	*Event*	*Course*	*Speed*	*Lap Speed*
16/7/22	French G.P.	Strasbourg	79.2 m.p.h.	87.75 m.p.h.
3/9/22	Italian G.P.	Monza	86.89 m.p.h.	91.3 m.p.h.

EXAMPLE No. NINE

The 1924 Sunbeam

WHEN the 2-litre formula was opened in 1922 Mr. Louis Coatalen, of the Sunbeam Company, engaged Henri as his chief designer. Discounting the hazards and misfortunes of racing, this engineer could fairly claim that he had produced the fastest formula cars for 1912, '13, '14, '19 and '20. No new design came from his board in 1921, but his 1920 Ballots were third in the French G.P. and won the Italian G.P. This was an impressive record and one may presume that he set to work on the Sunbeam project with abundant confidence. For various reasons, however, he abandoned the multi-cylinder principle which he had done so much to popularise with his Ballot-produced cars and chose a four-cylinder engine with characteristic large stroke/bore ratio, cast-iron cylinders, and unmistakable Henri valve gear. In the transmission he decided to use three speeds but retained the characteristic Hotchkiss drive. The front axle was notable for being constructed in three sections.

When put to the test these cars proved quite incapable of meeting the challenge of the six-cylinder Fiats with their greater piston area, two valves per cylinder and full roller bearing engines. Henri's engagement at Sunbeam was subsequently terminated. He was replaced by an ex-Fiat engineer, Bertarione, who copied the bulk of the 1922 chassis, into which he fitted an entirely new engine. The design of this, naturally enough, bore a very strong resemblance to the 1922 Fiats, the principal change being in a slight increase in bore and reduction in stroke.

These cars were victorious in the French Grand Prix at Tours in 1923 and in this way became the first British car to win a major international event. At the end of the year they were dismantled and completely rebuilt under Bertarione's supervision for 1924. They emerged as almost entirely new cars in which radical changes had been incorporated, particularly in the use of a supercharger for the power unit. Moreover, the supercharging in itself was on a then novel system in that the blower aspirated from the carburetter and delivered mixture under pressure to the manifold.

In 1924 this team of cars were undoubtedly the fastest 2-litres in Europe. As recounted elsewhere, only misfortune prevented them from winning the French Grand Prix two years in succession, and they secured the lap record. They won the Spanish Grand Prix of 1924, but by 1925, in which year the same cars were run, they had fallen behind in the matter of power per litre and were consistently outpaced.

In 1924 the car was hand-timed on the Lyons circuit at 130.5 m.p.h. for a flying kilometre, but there is reason to believe that this exaggerated the true speed. In September, 1924, this type averaged 114.23 m.p.h. over five miles, and, five years afterwards, when the engine was developing an additional 30 h.p., 126.08 m.p.h. for five kilometres. The lower of these speeds almost certainly does the car an injustice, but it is improbable that the true speed under neutral conditions would be more than an additional 10 m.p.h. A maximum of 125 m.p.h. is certainly not far from the truth.

Supercharging was by a Roots type blower mounted horizontally at the front of the crankcase and driven directly from the crankshaft, and the increased length of the engine with the blower on its nose meant that the 1923 frame had to be scrapped.

When rebuilt the car was 4 in. longer, 2½ in. lower and 275 lb. heavier than the previous year, the weight increase being due, not only to the greater overall dimensions, but also to the considerable revisions in the transmission. The previous car had an inverted cone clutch, three-speed gearbox and Hotchkiss drive. As can be seen from the cut-away drawing, the 1924 model was changed to torque tube drive ; it had a four-speed gearbox taking power from the Hele Shaw multi-disc clutch and in place of the right-hand gear change, a central lever was employed.

Taking 5,500 r.p.m. as maximum revs., the speeds on the various gears would be 100, 72 and 47 m.p.h. on the indirect ratios, whilst it is reasonable to assume that all these speeds could be raised by 5 per cent for brief periods.

The frame itself was comparatively small in section and well cranked in at the back in order to follow the line of the tapering tail, so that although the rear spring shackles came under the frame at the front end they were mounted on outriggers at the back end.

To allow for the angular displacement characteristic of torque tube drive, the axle beam was held on to the rear spring by split, white-metalled trunnion bearings. The springs were thereby totally relieved from either power or brake torque.

The brakes themselves are of interest because of the elaborate system of compensation and the use of a friction-servo motor. This design was actually a legacy from the 1922 Henri-designed four-cylinder models and on two of the team identical parts were used in the 1924 season. A cross-shaft mounted behind the gearbox drove (at reduced speed) a friction disc connected to the pedal. Movement of the pedal engaged the friction faces and these in turn applied front and rear brakes through the mass of cables and pulleys which constituted the compensating gear. The hand-brake worked on the rear drums only and a " racing ratchet " (as on the 1914 cars) was used. In this design the ratchet did not come into play unless a knob on the top of the handle was intentionally depressed by the driver.

The front axle followed the tradition of Henri design, being built in three sections, but was actually a new construction for the 1924 cars, which had a 4 in. greater track than the 1923 models. The rear axle dimensions were, however, left unchanged, this giving the car its noticeable crab-track appearance. The centre section of the front axle beam was tubular, the outer ends solid, each being bolted to the centre piece by a flange inside the spring pads.

A novelty in racing car design was the use of an oil cooler fitted beneath the radiator, but in 1925 the former component was deleted and heat dissipation was left to the very large oil tanks in the dry sump system. These can be seen placed on each side of the torque tube and together they hold more than 15 gallons of oil.

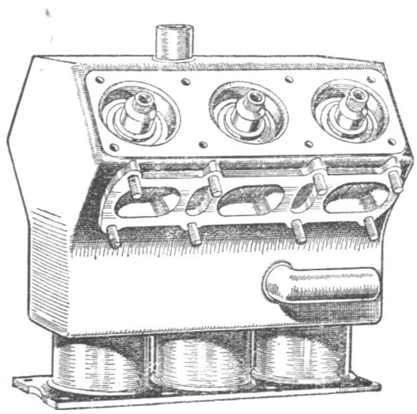
The undershield was cut-away beneath them and wire mesh panels inserted so as to provide air flow around the tanks.

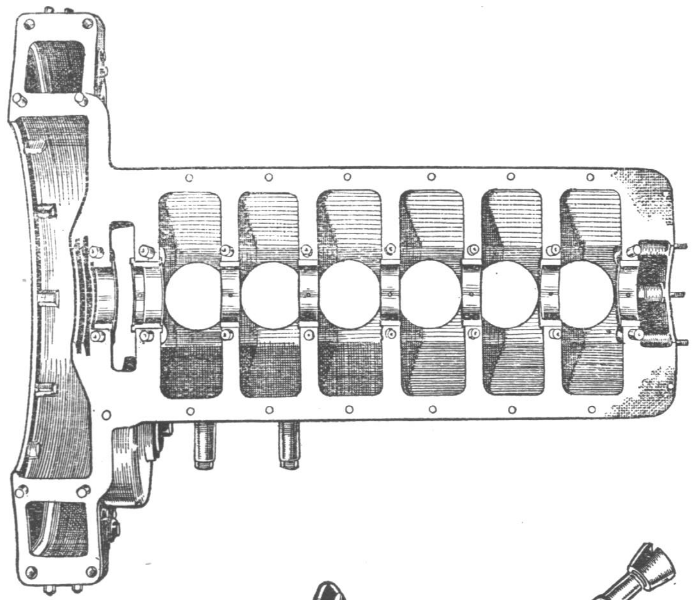
Another feature, rare at the time, was the spring-loaded escape valve for the radiator. An internal projection from the filter cap fitted fairly closely over the over-flow pipe, leaving only a small annular space between them. This made an effective baffle against water loss by surging when applying brakes hard and as a further safeguard a spring-loaded valve was placed at the farther end of the pipe and would only " blow

off” if steam pressure became considerable. In this event the steam was blown on to the driver’s right elbow so that he was aware that the radiator needed replenishment.

The drawings show the 1924 appearance of the car, but notes about two points are needed.

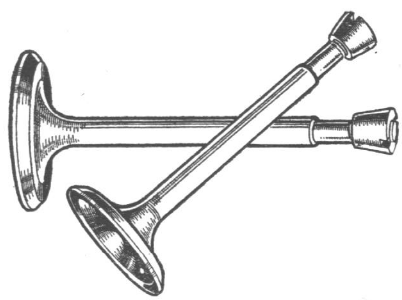
First, in both drawings the car is shown fitted with a V-shaped wire stone-guard. For some reason these do not seem to have been employed by the cars in the 1924 Grand Prix event, although they generally ran with them in position. Secondly, double Hartford shock absorbers are shown on the front axle, but it is likely that in the first race the cars had a single unit only.

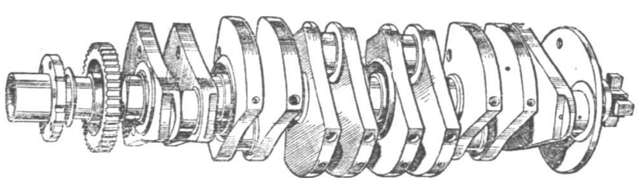




Top, left-A drawing of one block of the steel cylinder

Top, right-An inverted view of the top half of the crankcase





Lower, right-The inlet and exhaust valves, the latter of tulip form having 20 per cent less area than the former.

Left-The roller bearing crankshaft had eight bearings in all, two on each side of the rear timing gear wheel. The crank was counterbalanced and the big ends were of the roller-bearing type.

In 1924 engine design was at the turning point between the universal reliance upon induction at atmospheric pressure and the equally widespread employment of forced induction by a supercharger which has since followed. The details of these developments are recorded in another chapter.

The Sunbeam design has historic significance, not only in the fact that it was one of the first Grand Prix types to be supercharged, but that it was actually the first in Europe to compress mixture instead of pure air.

The illustrations of the Sunbeam engine show that the blower received mixture from the Solex carburetter through a rather long, curved pipe, the main object of this scheme being, apparently, to have the carburetter adjacent to the pits for adjustment if needed.

There are two principal advantages derived from sucking mixture from the carburetter through the blower, instead of blowing pure air to the carburetter. These are of such magnitude that all subsequent designers of blown engines have come to recognise them, the last to do so being Mercedes-Benz, who finally dropped their traditional blowing into the carburetter in the middle of 1937.

By pumping mixture full use can be made of latent heat given by the evaporation of fuel to reduce manifold temperature and much better mixing and distribution results from imparting mechanical carburation to the charge. Manifolds on racing engines should run at the lowest possible temperature and blowing air alone, a boost of 10 lb. per sq. in. results in a rise in temperature of approximately 80 degrees C. This, in turn, lowers the air density by 25 per cent, which reduces power to approximately the same degree.

High temperatures are also undesirable from a detonation point of view, so that there is a double reason for keeping the charge temperature down. By passing mixture through the blower the charge temperature can be kept at any desired figure simply by using enough alcohol in the fuel, the liquid having a high latent heat and also the valuable property that one can use exceedingly rich mixtures without losing power thereby.

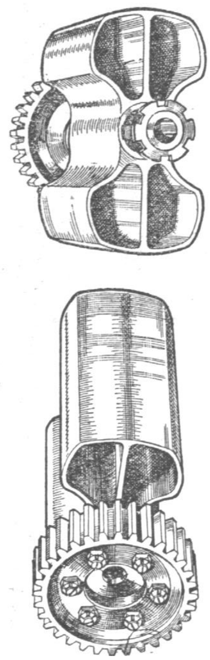
In view of the importance of this development, no little credit is due to Captain J. S. Irving, for his pioneer work in 1923-4, when chief engineer to the racing department at Sunbeams.

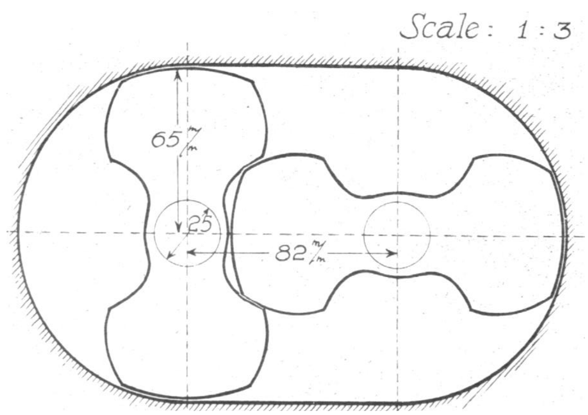
The blower was a normal Roots type, with, however, the interesting characteristic that the blower gears were mounted remote from the driving end so that all the drive torque of the blower had to be taken through one rotor shaft. This is an undesirable arrangement and has been abandoned on later designs of superchargers, but it must be confessed that no trouble seems to have arisen on this score on the engine in question.

The capacity of the blower was approximately 1.85 litres per r.p.m., so that the supercharge pressure of 6-7 lb. per sq. in. implies a volumetric efficiency of between 75 and 82 per cent. As will be seen, the mixture is supplied to dual three-branch manifolds, whilst on the bottom side of the supply pipe there is a large explosion valve with an off-take pipe projecting through the bottom cowling of the car.

The scale drawing of the rotor paddles shows that they were somewhat unorthodox in shape and gave a very wide seal between the case and the periphery of the rotor. Captain Irving observes that when the engines were being tested, violent knocking in the blower was experienced under certain conditions. This he eventually traced to a trapping of air in the recesses on each side of the shaft. The trouble was removed by milling a small flat along the small diameter. This allowed the air to pass from one side to the other as the rotors turned.

When originally assembled, the blower gave over 10 lb. per sq. in. boost, which was more than was needed, and is equivalent to a volumetric efficiency of approximately





The Roots blower rotors (left) were made from steel forgings and had connecting gears remote from the driving end. The scale drawing shows dimensions and the wide surface seal between the periphery of the rotors and the casing.

90 per cent. At the same time it was found that as the mixture temperatures rose there was certain distortion in the outer case and this necessitated increasing the clearances between the rotor and the casing, a very common modification in the development of all forms of blowers. The pressure dropped as a result to approximately 7 lb. per sq. in.

It will be seen that the crankcase was made from light alloy castings in two parts, with eight main bearings of roller type. The crankshaft is shown in a separate drawing which discloses the first of a train of timing gears at the back-end with a supporting bearing on each side. At the nose a four-star laminated spring drive was provided for the blower. The crankshaft was heavily counterweighted. The big ends were also of the roller type and the use of split cages and big ends in conjunction with roller bearings was a direct legacy from Fiat design. The construction has proved highly satisfactory and was used subsequently by Delage and Mercedes-Benz, but the highest standards of workmanship and fitting are required.

The connecting rod was a finely machined piece of work, and a point of particular interest was the deep ribbing of the lower cap.

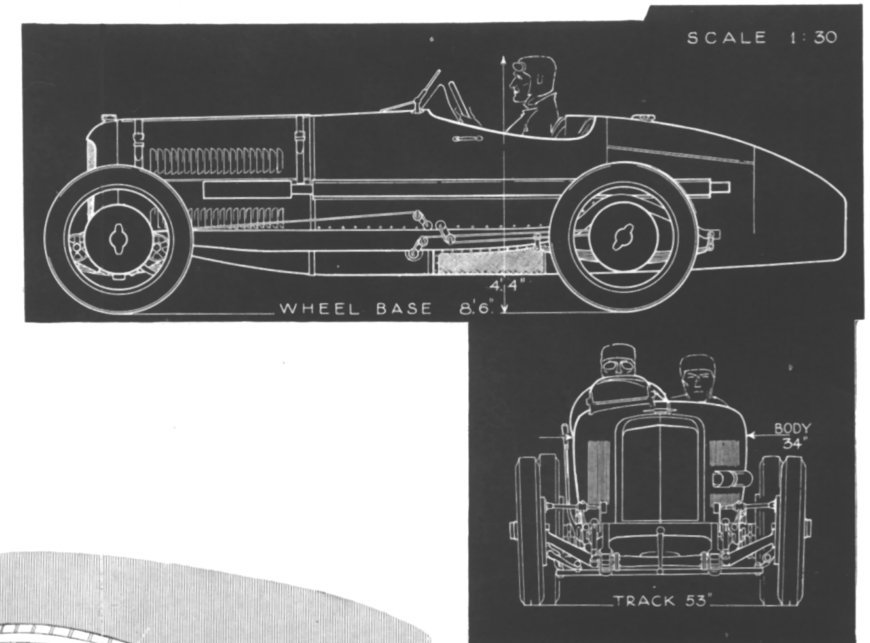
The cylinders were attached to the crankcase in two blocks of three, each cylinder being a separate forging welded to the bottom plate. These forgings constituted the cylinder barrels, with fixed heads, and a good deal of difficulty was experienced in welding them on to the bottom plate so that they were exactly in line. Once this had been done, the ports were welded up on to the head, and subsequently thin steel water jackets were welded around the entire assembly.

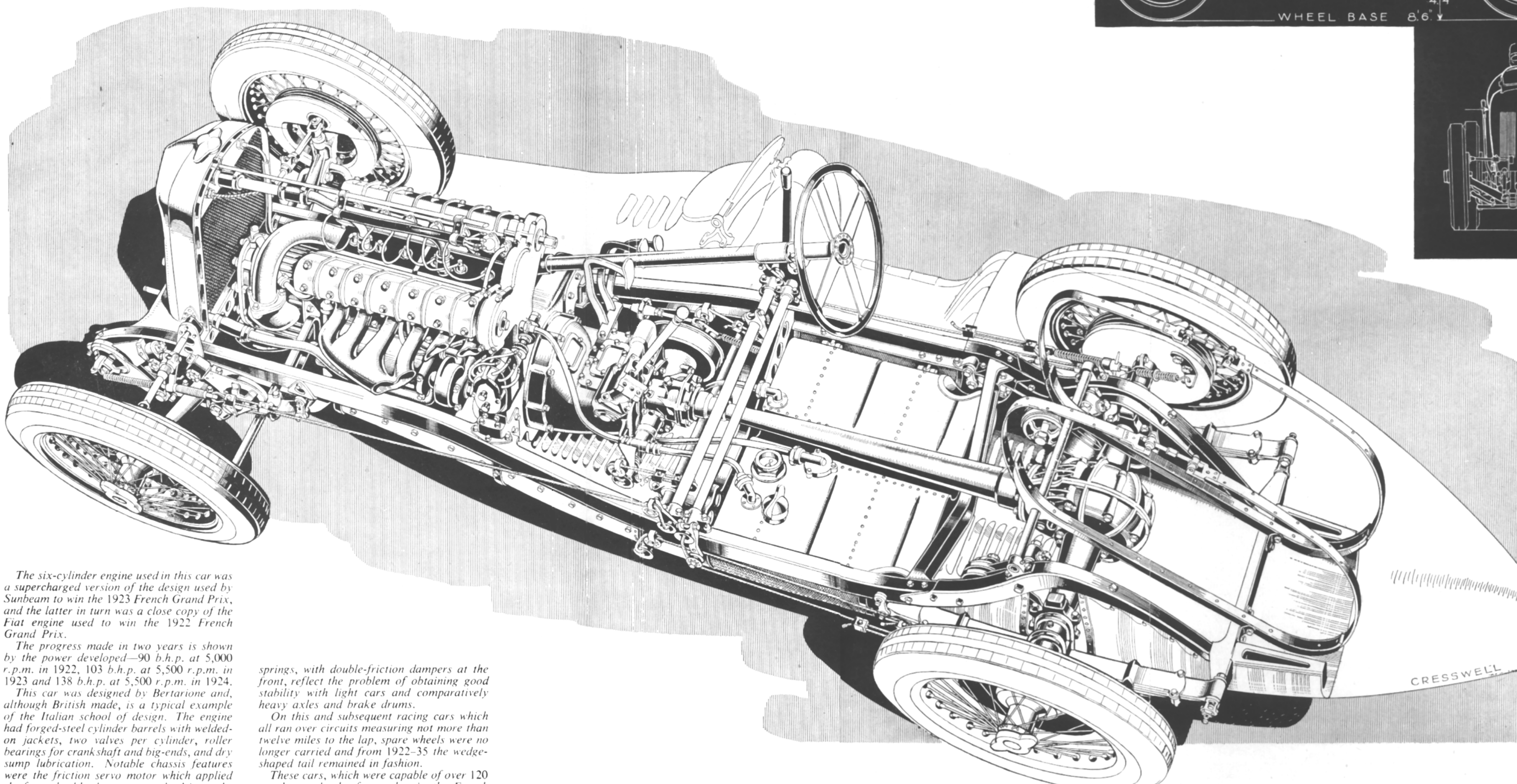
The result was two blocks of three cylinders, each having their own common water jacket, porting, etc., and bolted separately to the crankcase. The aluminium

PLATE XXI

EXAMPLE No. NINE

THE 1924 SUNBEAM





The six-cylinder engine used in this car was a supercharged version of the design used by Sunbeam to win the 1923 French Grand Prix, and the latter in turn was a close copy of the Fiat engine used to win the 1922 French Grand Prix.

The progress made in two years is shown by the power developed—90 b.h.p. at 5,000 r.p.m. in 1922, 103 b.h.p. at 5,500 r.p.m. in 1923 and 138 b.h.p. at 5,500 r.p.m. in 1924.

This car was designed by Bertarione and, although British made, is a typical example of the Italian school of design. The engine had forged-steel cylinder barrels with welded-on jackets, two valves per cylinder, roller bearings for crankshaft and big-ends, and dry sump lubrication. Notable chassis features were the friction servo motor which applied the four-wheel brakes, torque tube drive to the rear axle, and a swept-in frame which followed the taper of the tail. The short, stiff, springs, with double-friction dampers at the front, reflect the problem of obtaining good stability with light cars and comparatively heavy axles and brake drums.

On this and subsequent racing cars which all ran over circuits measuring not more than twelve miles to the lap, spare wheels were no longer carried and from 1922–35 the wedge-shaped tail remained in fashion.

These cars, which were capable of over 120 m.p.h., made the fastest lap in the French Grand Prix, and won the Spanish Grand Prix in 1924.

camshaft housings were, however, continuous castings, extending the whole length of the shaft and thus tied the unit together at the top end.

The valves, as have been previously stated, were inclined at 96 degrees, and operated through short steel pistons by two camshafts, these also running in ball bearings. Both cams gave a lift of 0.4 in., but the inlet valve had a 30 per cent greater area than the exhaust, the respective diameters being 1.625 in. and 1.437 in. at the throat. Quite a normal valve timing was used, viz. : inlet opens, 10 before T.D.C. ; inlet closes, 62 after B.D.C. ; exhaust opens, 50 before B.D.C. ; exhaust closes, 15 after T.D.C. A feature of the engine was high torque at low r.p.m.

The pistons were domed and slightly recessed at the sides to give clearance to the valves, and the compression ratio quite moderate, viz. : only 6 to 1. Two compression rings 2 mm. wide were employed with an oil scraper ring : there was also a bottom ring.

It is interesting to note that the diameter of the gudgeon pin was 18 mm., viz. : 27 per cent of the bore, a large figure for racing engines of those days.

Ignition was by Bosch magneto, driven by a skew gear at the rear of the engine, and incorporating a quick thread arrangement so that at all ignition timings maximum spark intensity was available. Sparking plugs were 18 mm. K.L.G. type 180. Incidentally, it is worth while mentioning that this type of K.L.G. plug had quite remarkable heat-resisting properties and was very much in advance of its time in this respect.

The plugs were masked as they were also in the Fiat design, the masking hole being approximately 4 in. deep and 10 mm. diameter, i.e. half the diameter of the plug.

During the 1924 Grand Prix Sunbeam cars were held back by misfiring, but this was later traced to defective magnetos, which had been installed the night before the race to replace instruments which had been carried over from the previous year. As run in this race, the engine developed 138 b.h.p., at 5,500 r.p.m., and the maximum speed of the car was approximately 125 m.p.h. Subsequently, certain developments were made which increased the power to 170 b.h.p. at 5,500 r.p.m. The position of the carburetter was changed and the blower casing heavily ribbed, the engine so modified being shown in a drawing in Part III.

Originally, the fuel was a mixture of approximately equal quantities of petrol, benzole and methyl alcohol petrol, made up by the Shell Co. Later the proportion of alcohol was increased.

The enhanced power naturally led to a corresponding gain in speed, and it is interesting to note that, whereas, in 1924, the five-mile record was taken at 114.23 m.p.h. by D. Resta, in 1929 it was raised to 126 m.p.h. by Jack Dunfee, who, in 1930, broke the 2-litre one-hour record at 117.49 m.p.h.

In the course of a long career in road racing, hill-climbing and track events engine failure was almost unknown and as a combination of reliability with performance the engines certainly have an outstanding record.

Acknowledgments.- A. S. Heal, Esq., has kindly placed one of the Sunbeam team cars at the disposal of author and artist, and J. L. Wyer, some-time member of the Sunbeam Experimental Department, has assisted with horse-power curves and data regarding the supercharging of these engines. Captain J. S. Irving, M.I.Mech.E., some-time chief engineer of the Sunbeam Company, has also given valuable assistance in the preparation of this chapter.

DETAILS OF CAR

MAKE.-Sunbeam
TYPE.-2-litre G.P.
YEAR OF CONSTRUCTION.- 1924
YEARS RACED.-1924 and 1925 in international racing; up to 1930 by constructors in other competitions.
DESIGNERS.- Coatalen, Henri, Bertarione.
WHEELBASE.-8 ft. 6 in.
TRACK FRONT.-4 ft. 5 in.
TRACK REAR.-4 ft. 1 in.
HEIGHT TO SCUTTLE.-45 in.
HEIGHT TO DRIVER'S HEAD.-52 in.
FRONTAL AREA.-10.8 sq. ft.
UNLADEN WEIGHT.-15.7 cwt.
ALL-UP STARTING LINE WEIGHT.-20.7 cwt.
MAXIMUM SPEED.-125 m.p.h.
SPEED ON INDIRECT GEARS.-100 m.p.h. on Third
,, ,, ,, ,, 72 m.p.h. on Second
,, ,, ,, 47 m.p.h. on First at 5,500 r.p.m.
H.P. PER SQ. FT.-12.7
H.P. PER TON UNLADEN.-176
H.P. PER TON ALL-UP.-133
BORE.-67 mm.
STROKE.-94 mm.
S./B. RATIO.-1.4: 1
NO. OF CYLINDERS.-Six
CAPACITY.-1,988 c.c.
PISTON AREA.-32.9 sq. in.
B.H.P.-138 at 5,500 r.p.m.
H.P. PER SQ. IN.-4.2
B.M.E.P.-170lb. sq. in.
PISTON SPEED FT./MIN.-3,400
CYLINDER HEAD.-Integral with steel barrel.
VALVES No.-Two per cylinder
VALVES ANGLE.-96 degrees
VALVE AREA-Inlet 12.5 sq. in.
VALVE AREA.-Exhaust 9.7 sq. in.
CYLINDER BLOCK-Steel barrels with welded ports and jackets in blocks of three
FUEL.-Petrol, Benzole, Alcohol
CARBURETTER.-Solex horizontal.
SUPERCHARGER.-Roots at engine speed.
MANIFOLD PRESSURE.-7 lb. boost (1.47 atm)
IGNITION.-one Bosch magneto
PLUGS No.-Six.
PLUGS LOCATION.-In centre of head
CRANKCASE.-Two-piece light alloy
CRANKSHAFT.-One-piece counterbalanced
MAIN BEARING No.-Eight
MAIN BEARING TYPE.-Roller
BIG END TYPE.-Roller with split big ends
LUBRICATION.--Dry Sump
CAMSHAFT No.-Two
CAMSHAFT LOCATION.-In head
CAMSHAFT DRIVE.-Train of gears
CAMSHAFT DRIVE LOCATION.-Bear of crank
CLUTCH.-Multi-plate
GEARBOX LOCATION.-In unit with engine
GEAR RATIOS.-3.75, 4.92, 6.96, 10.3
TRANSMISSION.-Torque tube location of bevel drive
FRAME.-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION-Semi-elliptic
SHOCK ABSORBER TYPE.-Hartford Friction
BRAKE SYSTEM-MECHANICAL.-Foot : through propeller shaft driven servo to all four wheels ; Hand : direct to rear wheels
BRAKE DRUM DIAMETER.-Front 14 in.
Rear 14 in.
BRAKE DRUM WIDTH.-Front 2 in.
Rear 2 in.
SQ. IN. PER TON LADEN.-330
STEERING.-Worm and wheel, 1-1/8 turns lock to lock
TYRES.-RAPSON.-Front and Rear 765 x 105
WHEELS.-Rudge-Whitworth knock-on

RACING RECORD

Date	*Event*	*Course*	*Average Speed*	*Lap Speed*
3/8/24	French G.P.	Lyons	69.6 m.p.h. (Fifth)	76.7 m.p.h.
25/9/24	Spanish G.P.	San Sebastian	62.54 m.p.h. (First)	67.42 m.p.h.
26/7/25	French G.P.	Montlhéry	68.2 m.p.h. (Third)	—

EXAMPLE No. TEN

The 1927 1½-Litre Delage

BEFORE the 1914-18 war Delage cars had a long string of competition successes, particularly in voiturette races. They built Grand Prix racing cars for the first time in 1913 and one of them was victorious in the 1914 Indianapolis event. In the 1914 French Grand Prix they entered a team of highly original cars with front brakes, five-speed gearboxes and positively closed valves. Although they made fast practice times they were disappointing, both in this event and in subsequent races in which they ran in the U.S.A.

Louis Delage took no part in 3-litre formula races, but in 1922 authorised the construction of a four-cylinder 2-litre engine with dimensions 70 x 130 mm. The engine showed up well on m.e.p., giving a figure of 125 lb. per sq. in. between 2,000 and 3,500 ft./min., but was deficient in piston area and only 80 b.h.p. was realised. It was, therefore, scratched from racing and replaced the following year by a twelve-cylinder 2-litre (51.3 x 80 mm.), designed by M. Plancton, having the remarkable piston area of 38.7 sq. in. This developed 120 b.h.p. at 6,000 r.p.m. in 1924 and 195 b.h.p. at 7,000 r.p.m. in supercharged form in 1925. In this latter year the car was highly successful; it won both the French and Spanish Grand Prix, made record laps in both events, and was acclaimed Champion of Europe.

M. Lory was largely responsible for the development of the car and he, aided by M. Gauthier, was entrusted with the design of a 1½-litre model to run under the formula recognised for 1926-7. This stipulated maximum cylinder capacity of 1½ litres, one occupant and a minimum width for the body of 80 cm. The minimum weight was 600 kilos for 1926 and was raised to 700 kilos in 1927 or, approximately, 11.8 and 13.8 cwt. respectively.

The car shown in the drawing and made the subject of this description is the 1927 model. Although based on the design of the earlier year it incorporated many changes; indeed, the difference between the two models is considerably greater than is generally realised.

On the 1926 models the exhaust pipes were placed on the right-hand side of the car, and throughout the year much trouble was caused by, and races lost, on account of the driver's feet becoming burnt. In 1927 the exhaust pipe was changed to the left-hand side and this involved removing the twin blowers, previously mounted centrally, and substituting a single blower on the nose of the timing cover. Other changes were a different design of radiator, thicker camshafts and considerably stiffer steering arms. There was an increase in weight from 14.76 cwt. to 15.8 cwt., both of these figures, it will be noted, being well above the minimum demanded.

These alterations had a considerable effect upon the fortunes of the design. Whereas the 1926 edition had only one win to its credit (the British Grand Prix), in 1927 the cars carried all before them, winning the French, the British, the Italian, and the Spanish Grands Prix.

The Brooklands speeds for this car are 117.19 m.p.h. for the flying lap and 95.78 m.p.h. for the standing lap, and one may reasonably deduce a maximum speed of a little over 125 m.p.h. This figure fits well with the speed of 129.75 m.p.h. realised by the eight-cylinder Talbot, of contemporary construction and identical cylinder capacity, over a F. S. Kilometre in 1926, for on lap speeds the Talbot showed itself slightly the faster car of the two.

In 1925 the riding mechanic disappeared, and as only the driver was, by the regulations, permitted in the car, the way was paved to a marked change in external appearance. It became possible, for the first time, to offset the whole transmission towards the mechanic's side of the car and to place the driver's seat very low down with the propeller shaft running past him at about thigh level.

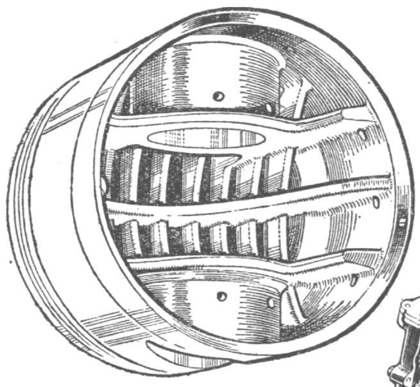
The Delage was the first design in which this principle was embodied, the bevel pinions being offset four inches to the left side of the car, making the proportions from the centre of the bevel box to the track 42.5 : 57 : 5 ; and by this means the height of the scuttle was reduced to 35 in. In consequence, although the body width could not be reduced to less than 31.5 in. the frontal area of the car came to the remarkably low figure of 9½ sq. ft.

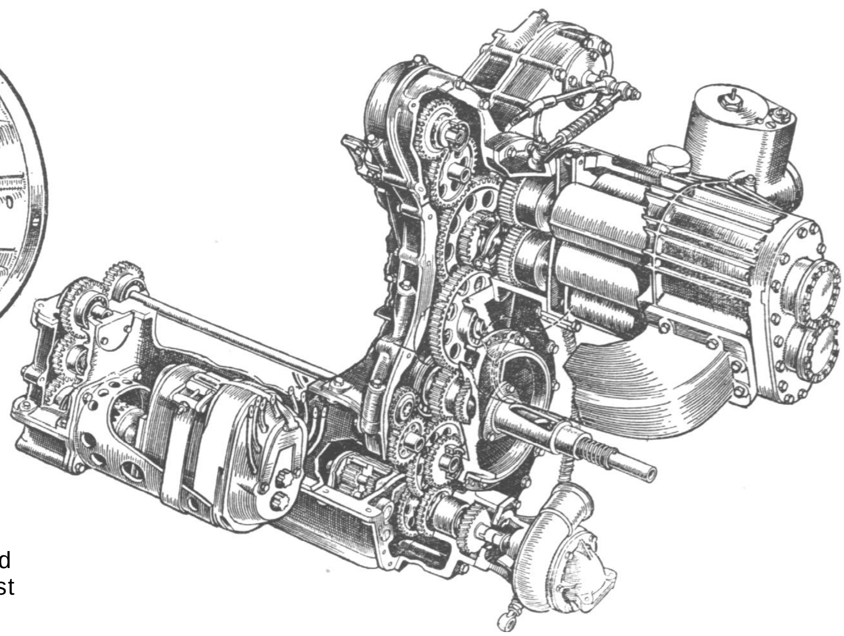
Thus, supposing that the engine power was in proportion to the capacity, one would have expected this 1½-litre model to have compared quite favourably with the 2-litre which had preceded it. In fact, however, the power-per-litre was increased to a remarkable extent, and although the sustained maximum r.p.m. cited were 6,500, the engine could be run at 8,000 r.p.m., at which speed it gave 170 b.h.p. in its original form. This is within 20 h.p. of the 1925 twelve-cylinder Delage and is equivalent to an m.e.p. of 177 lb. per sq. in., a particularly fine figure in view of the low boost pressure and moderate compression ratio. Whether the engine could be run continuously at 8,000 r.p.m. is somewhat doubtful, and it is significant that the transmission included a five-speed gearbox with a fifth speed which reduced engine r.p.m. by 19 per cent. On this gear 8,000 r.p.m. would correspond with 162 m.p.h., which would have demanded far more horsepower than was available, and it is likely that 132 m.p.h. at 6,500 r.p.m. was the maximum ever attained on this gear in exceptionally favourable circumstances. It will, however, be seen that the driver had the option of running at, say, 128 m.p.h. at either 6,300 in overdrive or 7,500 r.p.m. in direct. A multi-plate clutch lay between the engine and the gearbox and the latter was of extreme length which, taken in conjunction with the engine mounting, resulted in there being virtually no cross bracing between the radiator and the driver's seat. This gave the car a characteristic weaving motion that affected the steadiness on the straight and impaired handling qualities on corners.

As a further result of the unusual length of the engine gearbox unit the open propeller shaft was particularly short. The rear axle assembly had a centre section built up from two steel forgings bolted together on the centre line, the outer halves being made from ball-mouthed steel tubing less than 5 mm. wall thickness. No light alloy entered into the construction, but this notwithstanding, the entire assembly was very much lighter than many more modern designs which make the extensive use of non-ferrous materials. Alternative crown-wheels and pinions were available, giving final axle ratios as low as 6.1: 1 and as high as 4.7: 1, but it may be taken that 5.2: 1 was a normal ratio on which the figures in the data panel have been based. The considerable

lateral offset of the bevel box to the near side has already been mentioned, and, in consequence, the steering column came into the position normal to a two-seater car.

On the 1927 model great attention was given to rigidity of the steering connections and these were all made of very deep section so as to resist the stresses imposed upon them with the minimum of deflection. The steering mechanism was of the worm and wheel type with a ratio giving 1½ turns of the hand wheel from lock to lock. The wheel itself was of the René Thomas flexible type. A sketch shows the massive proportions of the off-side stub axle and these were duplicated in the drop arm and the corresponding near-side wheel linkage.





Above-Details of the pistons

Right-The mass of auxiliary and camshaft drive gears of almost legendary fame

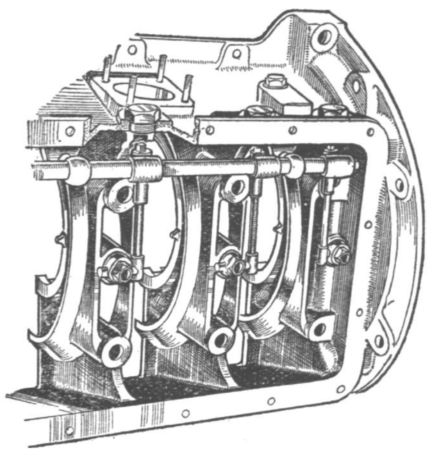
The brakes were of moderate diameter-approximately 14 in. internal, light alloy, non-servo shoes in all four wheels being applied by an internal expanding friction servo driven off the back of the gearbox. In this, movement of the pedal expands small brake shoes which grip a freely mounted drum and the tendency of this to turn is transmitted to the brake linkage to front and back wheels. Such a device enables high unit pressures to be used without excessive pedal effort, but has the disadvantage of being unsympathetic in action and liable unexpectedly to lock the wheels. In order to avoid this, the front brake arms were arranged to give a negative servo effect. It will be seen that pendant levers were pulled forward by a chain run over a sprocket. Hence, as the front brakes come on and the axle tends to twist forward on the springs, there is a " letting go " action, whereas if the levers had been pulled straight backwards the axle twist would have caused the brakes to go on harder and harder.

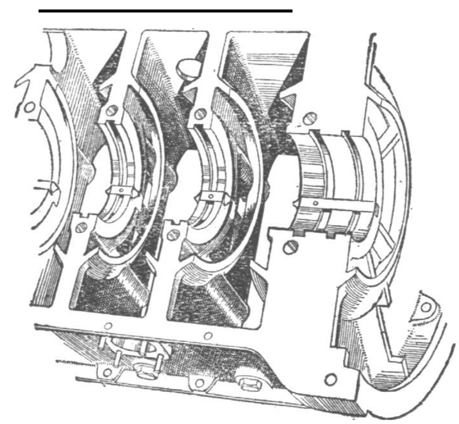
Semi-elliptic springs were used fore and aft, being short and stiff, as can be gauged from the fact that the minimum ground clearance between the central oil tank and the road is about 3 in. Friction-type shock absorbers were fitted to both front and rear axles and placed inside the bodywork.

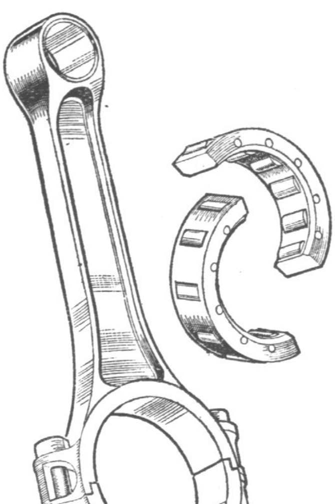
In order to find adequate area for the radiator with its low height, the bottom tank had to come very low to the ground-in fact, well below the front axle beam. For

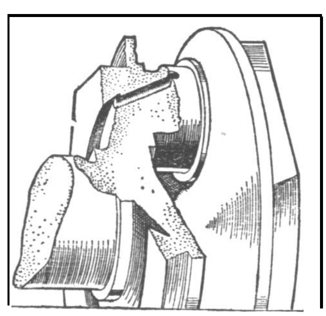
this reason it was placed ahead of the front axle and a long pipe carried the water back to the exhaust side of the cylinder block. The water pump was driven by the front timing wheels and the radiator core was of the tubular type-possibly one of the earliest departures from the honeycomb form on a modern racing car.

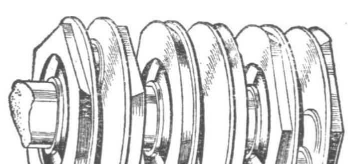
In addition to low frontal area the car was well streamlined without going to the more complete aerodynamic form. The shock absorbers were mounted out of the slipstream, and the bottom of the car fitted with a full-length light alloy under-tray. The tail was entirely filled by the petrol tank and the filler caps covered by a flap.











These detail views of the crankcase, crankshaft and a connecting rod demonstrate the emphasis on rigidity planned by the designer. In particular the heavy section connecting rod which weighed 14½ ozs. is noteworthy

In addition to the sound general design seen in the drawing there are almost innumerable detail items of value, only a few of which can be mentioned. One of these is a lock which prohibits the use of either third, fourth and fifth ratios, or first and second. By moving one of these small catches the driver can be quite sure of not getting into the wrong ratio when once he knows the type of course on which he will be running. The gear positions were first, right-hand forwards, and top, left-hand backwards, with overdrive extreme left-hand forwards. It may be presumed that the real object of the catch was to make sure that the driver brought the lever back, slightly right and back

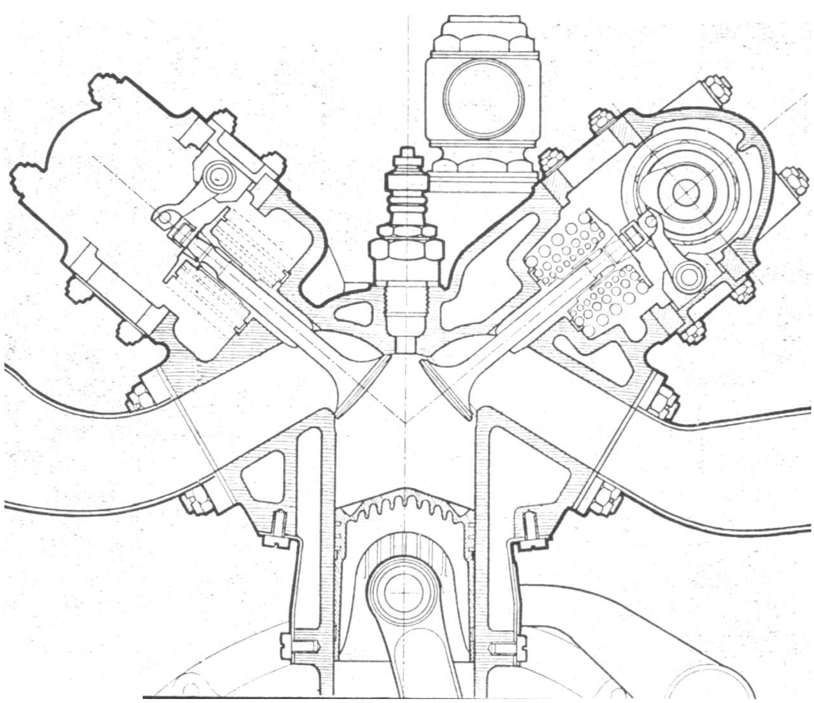
again to engage direct drive and not too far across to the right, which would engage second gear, with disastrous results to the transmission and engine.

Another point is the fixing of the steering column on to the dashboard by means of a miniature rack and pinion. This makes a very solid fixing, but at the same time, by slackening off one face and loosening the mounting bolts on the steering box, the column can be raised or lowered and then fixed in the new position with the greatest of ease.

A touchstone by which we may fix the success or otherwise of a racing car is the advance it represents in power output, subject to its achieving reasonable standards of reliability. By this test, the l½-litre Delage engine was truly a milestone in design, for whereas in 1925 the 2-litre twelve-cylinder Delage developed 190 b.h.p.-viz., 95 b.h.p. per litre-in 1926 the l½-litre model developed 170 b.h.p., equal to 113.5 b.h.p. per litre, or a gain of nearly 20 per cent.

The gain in terms of h.p. per sq. in. of piston area was much less and from this absolute viewpoint there is, indeed, very little difference in merit between these two engines.

Reliability was first class. The Delage Company ran twenty cars in seven races during the period 1926-27, out of which they won five, finished first, second and third in two, and had three retirements due to engine trouble. Ten years afterwards, Richard Seaman ran for a complete season without engine trouble and, in fact, won three races in succession without any adjustment being carried out, probably a record in the history of the racing automobile.



This cross-section of the Delage shows the large angle of inclination of the valves, the concentration of water round the exhaust valves and the large diameter gudgeon pin. (Scale I : 3)

When examining the engine in detail, one sees that designer Lory was imbued by the maxim " Nothing too much trouble : no expense spared."

The bottom half of the engine, truly the fount of reliability, was made from three light-alloy castings divided horizontally. The bottom one was merely a shallow tray, which acted as an oil collector for the dry-sump lubrication. The other two halves carried the nine roller bearings for the crankshaft, which were 10 mm. wide by 49 mm. in diameter, and the crank itself had circular webs, the big ends being 32 mm. diameter. The crank was in one piece, hardened and ground all over, and each big end lubricated by an ingenious arrangement of jets. As can be seen from a detailed drawing, oil was fed through a gallery pipe to each bearing, eventually meeting a three-piece unit. The centre jet sprayed oil on to the main roller bearing, and the two jets at right angles thereto sprayed oil sideways on to the crank web. This had an annular recess to collect the oil and pass it under centrifugal pressure to the big end.

Although the oil pressure was only between l-2 lb. per sq. in. a large volume was provided and, with good fitting bearings, troubles on these engines were almost unknown. Such a scheme is, of course, only suitable for roller bearing big ends, and in this case each connecting rod ran on twelve rollers, each 6½ mm. diameter and 11 mm. long. These were located in a split light-alloy cage, each half looking after six rollers and the complete assembly weighing 2¼ oz. No particular trouble was taken to ensure that the two halves of the cage exactly matched but accuracy on the internal track of the split big end is vital to success.

The lower half of the rod was deeply ribbed for rigidity, and a feature was the easy radius between the shoulder of the big end and the H-section part of the rod. The complete rod with the big end assembly weighed 14½ oz., and its stiffness had obviously been very much in the eye of the designer.

This stiffness was obtained not only by the section of the rod, but also by its shortness, for it was only twice the length of the stroke-a low figure-whilst the gudgeon pins, 22 mm. in diameter, were only 31 per cent smaller than the big ends and measured nearly 40 per cent of the cylinder diameter.

To conclude this review of the reciprocating parts, the original pistons gave a compression ratio of approximately 6.5 to 1, and were exceedingly light die-castings, weighing only 5¾ ozs., complete with rings. The gudgeon pins weighed a further 2 oz., hence the total reciprocating weight of this engine amounted to 22 oz.

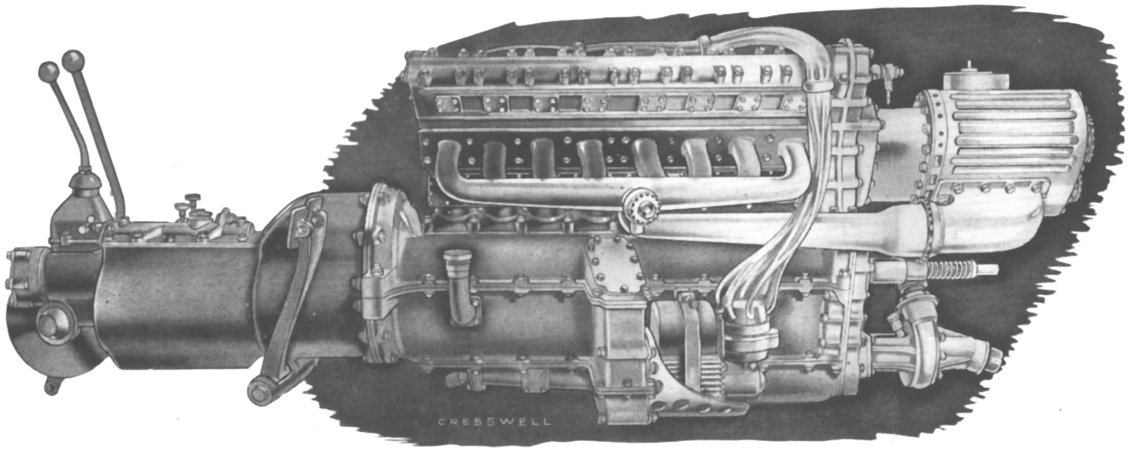
The layout of the crankshaft was distinctly unusual. The angles relative to No. 1 crankpin were : No. 2, 90 degrees ; No. 3, 180 degrees ; No. 4, 270 degrees ; No. 5, 270 degrees ; No. 6, 180 degrees ; No. 7, 90 degrees ; and No. 8, 360 degrees, reading the degree scale clockwise.

This scheme would involve difficulties on a production crankshaft, although these disappear if the crank, as in this case, was machined from the solid. There appear to be no particular virtues in the arrangement from the view-point of balance, but the firing order given (viz. : l-8-3-5-7-2-6-l) may give better balance of flow than the more orthodox l-3-2-5-8-6-7-4 which has been used on the Alfa Romeo and other more recent cars.

Just as rigidity had been uppermost in the designer's mind when tackling the bottom half of the engine, so it is plain that problems of volumetric efficiency were most carefully considered when dealing with the upper part of the engine. Each

EXAMPLE No. TEN

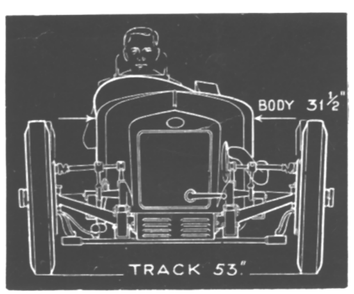
THE 1927 DELAGE

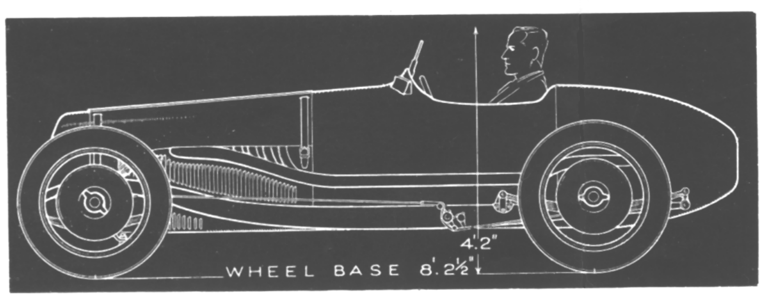


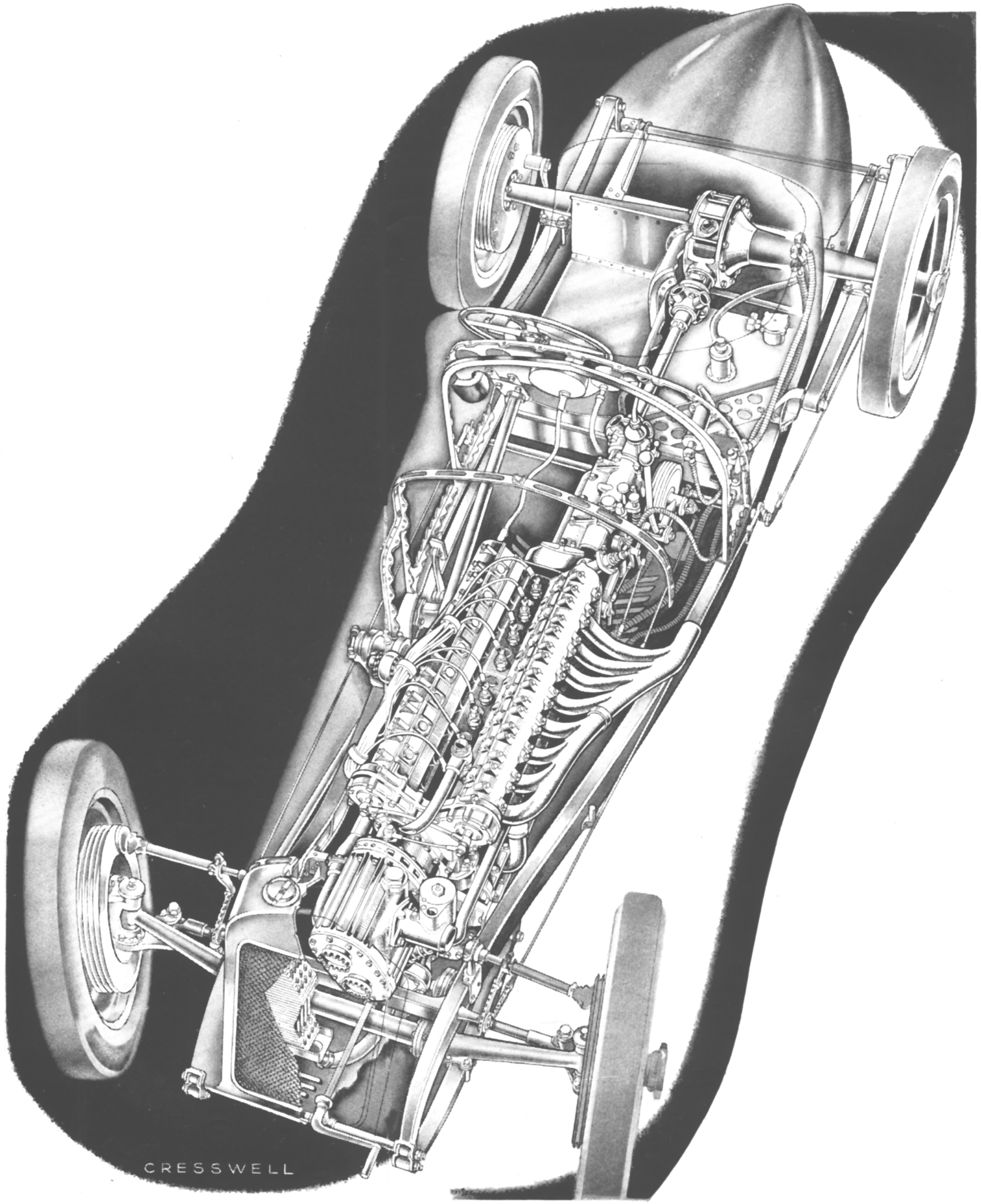
This car was designed by Lory to a formula limiting capacity to 1½ litres and requiring the driver only as crew. Despite the engine size, 177 b.h.p. was obtained by combining super-charging, eight small cylinders, and an engine speed of 8,000 r.p.m., although to ensure reliability a five-speed gearbox with an overdrive permitted the maximum speed of 127 m.p.h. to be reached at 6,500 r.p.m. Owing to the very small stroke of 76 mm. the piston speed at this r.p.m. was within normal limits. The two valves per cylinder were placed at an included angle of 100 degrees, and the ports were so carefully designed that the volumetric efficiency considered in relation to the boost pressure has rarely been exceeded. The engine also had a remarkably high mechanical efficiency, roller bearings being used throughout the whole of the crankshaft assembly and for almost all of the auxiliary drives, the total number of bearings of this kind being no less than 48. The cylinder block was in one iron casting.

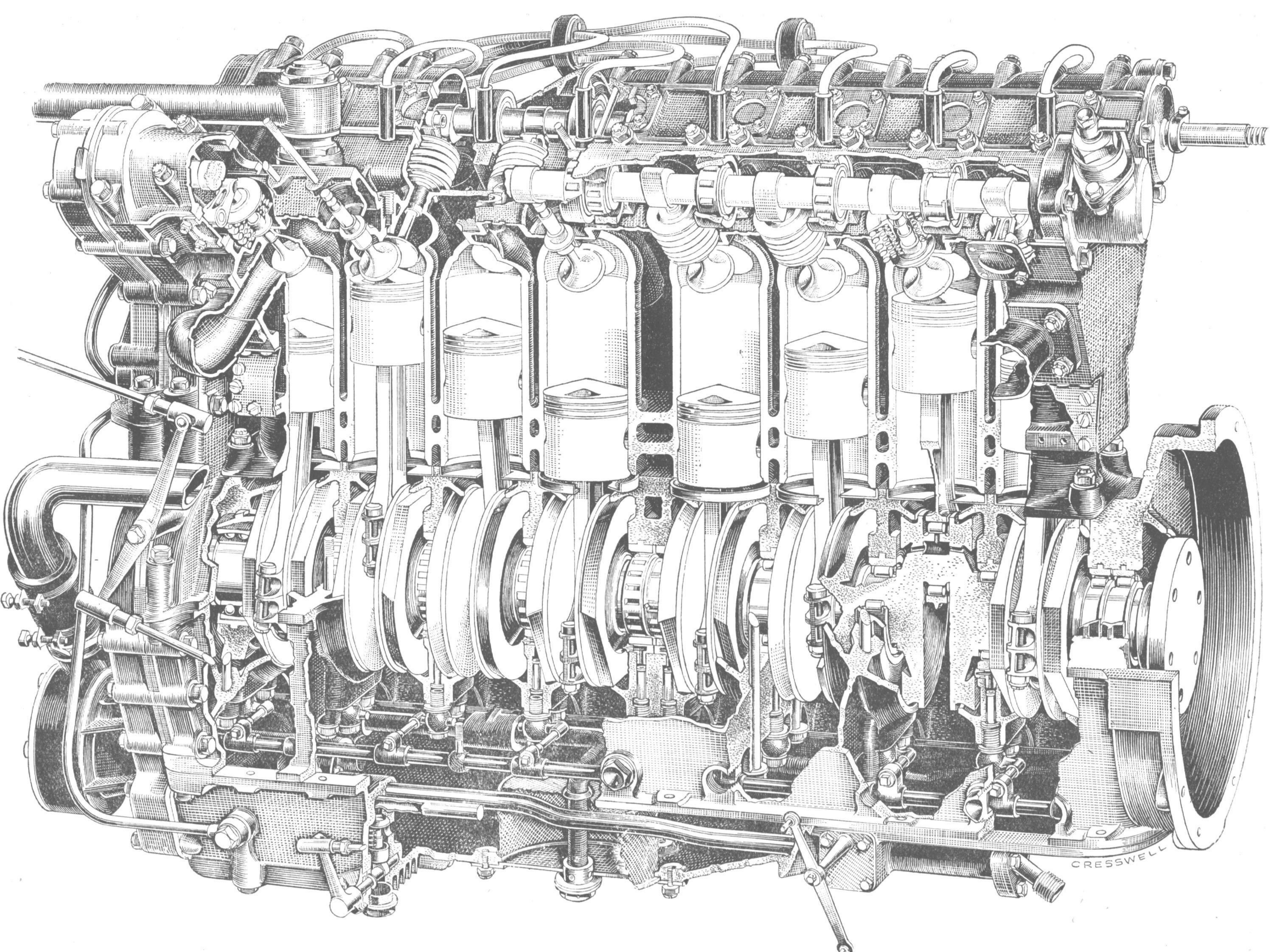
Engine and transmission were offset, thereby lowering the driver and reducing frontal area.

The extreme length of the engine and gearbox unit and the corresponding lack of bracing from the front hub centres to the scuttle is particularly well shown in this drawing. A further point of interest is the friction-type servo motor which, driven off the back of the gearbox, augmented the brake pedal pressure. The arms on the brake cross shafts are pulled forward so that movement of the axle on the springs does not itself set up a self-locking action. This car proved itself to be faster than the preceding 2-litre models, was unbeaten in 1927, and was winning races in the 1½-litre category ten years after its date of construction.








CRESSWELL

cylinder had one inlet and one exhaust valve inclined at 50 degrees. This angle permitted the inlet valve to be a good deal more than half the diameter of the bore, the exact size being 3 1 mm. as against an exhaust valve of 29 mm. The 7 mm. lift of the valves was moderate. The inlet valve opened 18 degrees B.T.C. and closed 50 degrees A.B.C. ; the exhaust opened 58 degrees early and shut 25 degrees late, the overlap, therefore, being 43 degrees. Triple valve springs were used and rather small followers were interposed between the cam and the valve stem, these being one of the least satisfactory parts of the engine and liable to rapid wear.

The design of the inlet manifold is interesting ; nowhere is a constant diameter followed, but, on the other hand, the cross-sectional areas seem carefully planned to meet the gas flow requirements at each individual point.

The m.e.p. and r.p.m. figures are certainly matters on which the designers deserve congratulation, particularly bearing in mind the comparatively low boost pressures employed. A b.m.e.p., of 177 lb. per sq. in. at 8,000 r;p.m., with only 7.5 lb. boost, is very creditable and certainly implies a high mechanical efficiency despite a stroke/bore ratio of 1.36:1, which gives a maximum piston speed of no less than 4,000 f.p.m.

The Roots blower had a theoretical capacity of 1.4 litres and ran at engine speed, being driven off the train of gears which connects the crankshaft to the two camshafts. There seems little doubt that it was a direct legacy from the twin blowers which were fitted to the twelve-cylinder 1925 cars, one on each side of the crankcase. The 1926 edition of the Delage engine followed the practice of two blowers, these presumably having the same rotor form and being made slightly shorter than the old 2-litre models. They were driven from a gear placed roughly in the middle of the nearside of the crankcase and driven by a lay-shaft from the front timing. Each blower had its own carburetter and fed to manifolds bolted direct on to the near side of the cylinder block.

In 1927 the cylinder block was re-designed so that the exhaust could be transferred to the near side and, as the magneto already occupied the middle of the off side of the crankcase, the blower was put on the nose of the timing case.

A single unit now replaced the previous twin blowers, so the length of the rotors had to be doubled from 110 mm.-a convenient figure giving good stiffness-to 220 mm., which was really too long. However, at the comparatively low pressures used, the blower does not appear to have given any trouble.

At the front of the engine lay the mass of the timing and auxiliary drive gears which have secured an almost legendary fame. The camshafts were not symmetrically mounted on the cylinder head and the gearing to the inlet and exhaust shafts was not, therefore, interchangeable. The camshaft drive involved no less than eight gears, to which should be added seven to the magneto, two to the oil pump, and two to the water pump, whilst originally there were a further four for the supercharger installation, all of these running on roller bearings.

The pumps for the dry-sump lubrication system were housed in the bottom section of the crankcase, and a by-pass valve from the pressure side inter-connected with the accelerator pedal so that on full throttle there was a substantially higher oil pressure and greater circulation than on part throttle. This scheme is open to the objection that the highest loading in the engine (due to inertia) will occur with the throttle shut and virtually no oil circulation, but presumably the drivers were forewarned to avoid this condition as much as possible.

The cylinder block was a single iron casting with open sides covered by steel sheets. A centrifugal pump mounted on the front of the crankcase supplied water to the near side of the block from whence it circulated up through the head which was so designed that a large mass of water surrounds the exhaust valves and ports. Much of the success of the engine must be attributed to the good water flow. A cross-section brings this point out very clearly.

The 18 mm. sparking plugs were masked, the diameter of the inter-connecting passage being 8 mm., whilst the camshafts ran in a split light housing with a ball bearing placed on each side of each cam. Lubrication was through the centre of the camshafts, the diameter of which was increased considerably as between 1926 and 1927.

The Delage engine literally represents a technical *tour de force* both in design and construction, the casting of the eight-cylinder block in itself being an achievement of no mean order.

On the other hand, the engine was heavy and measured 55 in. from the timing case to the rear universal joint. This in conjunction with the method of engine mounting led to a frame which was very weak in torsion and it can be argued that excellent engine design was offset to a material extent by deficiencies in chassis layout.

Acknowledgments.-R. Parnell, Esq., has been of the greatest assistance in providing a complete car with components and drawings upon which this chapter has been based.

RACING RECORD

Date	*Event*	*Course*	*Average Speed*	*Lap Speed*
18/7/26	European G.P.	San Sebastian	— (Third)	81.5 m.p.h.
7/8/26	English G.P.	Brooklands with Chicanes	71.61 m.p.h.	—
3/7/27	French G.P.	Montlhéry	77.24 m.p.h.	81.43 m.p.h.
31/7/27	Spanish G.P.	San Sebastian	80.52 m.p.h.	85.41 m.p.h.
4/9/27	European G.P.	Monza	90.04 m.p.h.	94.31 m.p.h.
1/10/27	English G.P.	Brooklands with Chicanes	85.59 m.p.h.	—

DETAILS OF CAR

MAKE.-Delage
TYPE.- 1½-litre G.P.
YEAR OF CONSTRUCTION.-1926-27
YEAR RACED.-1927, by manufacturers
DESIGNER.-Lory
WHEELBASE.-8 ft. 2½ in,
TRACK FRONT.-4 ft. 5 in.
TRACK REAR.-4 ft. 5 in.
HEIGHT TO SCUTTLE.-35 in.
HEIGHT TO DRIVER'S HEAD.-50 in.
FRONTAL AREA.-9½ sq. ft.
UNLADEN WEIGHT.-15.8 cwt.
ALL~UP STARTING LINE WEIGHT.-19.3 cwt.
MAXIMUM SPEED.-128 m.p.h. on 5.2:1 direct 4th at 7,500 r.p.m.
THEORETICAL MAXIMUM AT 8,000 R.P.M. on 5TH OVERDRIVE.-162 m.p.h.
SPEED ON INDIRECT GEARS.-108 on Third
" " " " 82 on Second
" " " " 61 on First at 8,000 r.p.m.
H.P. PER SQ. FT.-18 on direct top
H.P. PER SQ. FT.-145 at 130 m.p.h. on overdrive 5th.
H.P. PER TON UNLADEN.-215
H.P. PER TON ALL-UP.-177
BORE.-55.8 mm.
STROKE.-76 mm.
S./B. RATIO.--1.36:1
No. OF CYLINDERS.-Fight
CAPACITY.-1,488 cc.
PISTON AREA.-31 sq. in.
B.H.P.-170 at 8,000 r.p.m.
H.P. PER SQ. IN.-5.8
B.M.E.P.-177 lb. sq. in.
PISTON SPEED FT./MIN.-4,000
CYLINDER HEAD.-Cast-iron integral with block
VALVES No.-Two per cylinder
VALVES ANGLE.-1 00 degrees
VALVE AREA-INLET.-9.30 sq. in.
VALVE AREA EXHAUST.-8.16
CYLINDER BLOCK.-Cast-iron in one block with detachable plate on water jackets
FUEL.-Petrol, Benzole, Alcohol
CARBURETTER.-Cozette horizontal
SUPERCHARGER.-Roots at engine speed
MANIFOLD PRESSURE.-7 lb. boost (1.47 atm)
IGNITION.-one Bosch magneto
PLUGS No.-Eight
PLUGS LOCATION.-In centre of head
CRANKCASE.-Two-piece light ahoy split on bearing centre line with detachable sump bolted on.
CRANKSHAFT.-One-piece counterbalanced
MAIN BEARING No.-Nine
MAIN BEARING TYPE-Roller
BIG END TYPE.-Roller with split big ends
LUBRICATION.-Dry Sump
CAMSHAFT No.-Two
CAMSHAFT LOCATION.-In head
CAMSHAFT DRIVE.-Train of gears
CAMSHAFT DRIVE LOCATION.-Front of crank
CLUTCH.-Multi-plate
GEARBOX LOCATION.-In unit with engine
GEAR RATIOS.-4.4 (overdrive), 5.2 (direct), (alternatives 4.7 highest, 6.1 lowest), 6.6, 8.75, 11.7
TRANSMISSION.-Open propeller shaft to bevel drive rear axle
FRAME.-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBER TYPE.-Hartford Friction
BRAKE SYSTEM.-Mechanical, foot through propeller shaft driven servo to all four wheels ; hand, to rear wheels.
BRAKE DRUM DIAMETER.-Front 14 in.
Rear 14 in.
BRAKE DRUM WIDTH.-Front 1½ in.
Rear 1½ in.
SQ. IN. PER TON LADEN.-270
STEERING.-Worm and Wheel 1½ turns lock to lock
TYRES.-Michelin 765 x 120 Front and Rear
WHEELS.-Rudge-Whitworth knock-on

EXAMPLE No. ELEVEN

The Type 35 Bugatti

BUGATTI cars have won more road races than any other make, quite possibly more than all other makes added together. This is all the more remarkable in that when Ettore Bugatti had his works situated in German-administered Alsace he took but little part in racing. His post-1919 Grand Prix types were not immediately successful, although one of the 1922 straight-eight 60 x 88 mm. 2-litre cars ran second in the French Grand Prix at Strasbourg, and his remarkable tank-type streamlined car, using the same engine, was placed third in the 1923 French Grand Prix at Tours. In 1924, however, a basically unchanged engine was installed in an entirely new chassis which, given the type number 35, commenced the remarkable run of successes associated with this marque. This model broke the lap record in the 1924 Spanish Grand Prix and, in the following two years, Bugatti cars achieved a total of 1,045 victories, including, in 1926, the French, European and Italian Grands Prix, using a modified power unit of l½ litres capacity. This l½-litre, the Type 39, was less successful in the 1927 formula races, but in other events 806 wins were realised in this year. So many successes were based on the fact that the Type 35 Bugatti was at once a racing car and a catalogue model which was used very largely by amateur drivers. In 1928, '29 and '30, in the period of *formule libre,* Bugatti fortunes were at their zenith and fourteen victories of the first order were secured in these three seasons.

During these years, the chassis design, which was conceived for the French Grand Prix at Lyons in 1924, was untouched, apart from minor changes to wheels, brakes and the radiator. The 1922 engine was substantially modified in 1925 by the use of a built-up crankshaft with five main bearings and roller-bearing connecting rods with one-piece big ends. This arrangement took the place of a shaft running on three roller bearings but carrying white metal big ends. The cylinder dimensions remained unaltered at 60 x 88 mm., and for the duration of the 2-litre formula Bugatti remained faithful to atmospheric induction, endeavouring, not unsuccessfully, to offset deficiencies in power with superior road holding and chassis design.

The change to a l½-litre formula in 1926 made forced induction essential and led to the introduction of the Type 39. This was the successor of a l½-litre eight-cylinder built for the French Touring Car Grand Prix run at Montlhéry in 1925 under a limit of 12.8 m.p.g. and the engine was really identical to the Type 35 except that capacity was reduced by changing the cylinder dimensions to 52 x 88 mm., and a Roots type supercharger was mounted on the offside of the crankcase and driven from the front end of the crankshaft by a train of gears. Bugatti showed his essential versatility by simultaneously developing an alternative model with 2.3 litres capacity, having dimensions 60 x 100 mm., termed the Type 35B. This, supercharged in the same way as the Type 39 but with a correspondingly larger capacity blower, ran in and won the 1926 Targa Florio which was a *formule libre* event. This car was followed in 1927 by the Type 35C, which had the original bore and stroke of 60 x 88 mm., but supercharged .and with larger radiator, more forwardly mounted, and bigger brake drums than the 1924 cars.

In maximum speed there was practically nothing to choose between these models ;

in fact, the evidence of the record book seems to indicate that the l½-litre variation may have been the fastest of them all.

In 1928 the Type 35B model secured a standing kilometre record at 76.27 m.p.h. and the standing mile at 85.14 m.p.h. The same car averaged 122.5 m.p.h. over a flying kilometre, and although these speeds were subsequently slightly exceeded they may be taken as representative of the performance of this model.

In 1930 the Type 35C averaged 83.44 m.p.h. for the standing kilometre and 94.01 m.p.h. for the standing mile, giving an intervening speed of 119 m.p.h., but it was incapable of breaking flying records in the face of the superior top speed of such cars as the P.2 Alfa Romeo and twelve-cylinder Delage, which would exceed 130 m.p.h.

One would expect from engineering statistics that the Type 35 Bugatti, even in supercharged form, would be a somewhat slow car, and this expectation, borne out by measured performance, makes it all the more remarkable that the average circuit speeds of the Bugatti should be so high.

It is thus apparent that there was something about the Bugatti design enabling each horse-power to be utilized to far better advantage than on other racing cars of its period. The secret of this maximum realisation of power is to be found in the extraordinary controllability, road holding, and general stability of the Bugatti cars, qualities which the Types 35 B and C share with practically every other product from Bugatti's drawing-board and which derive from the excellent chassis design..

A unique feature of this, and all other Bugatti cars, is the reversed quarter-elliptic springs connected to the rear axle by shackle bolts. In consequence a radius arm is necessary to deal with the driving torque for which purpose (on this particular model) two external arms, with ball joints, are attached to the frame. The latter makes an interesting study in itself, and shows the familiarity of the designer with the fundamentals of design. The depth of the frame varies continuously throughout its length in accordance with the loads imposed upon it so that although inspection of the dumb-irons, which are only three-quarters of an inch deep, gives an impression of the utmost frailty, the depth of the frame members at the mid-point is 6¾ in.

Torsional strength is even more important in frame design than beam strength. The Bugatti frame in itself is not very good in this respect, but the car as a whole is exceedingly rigid. The two dumb-irons are tied together by a tube, whilst the straight-eight engine, being rigidly anchored at four points, ties up the entire front part of the frame in an admirable fashion. The back part of the frame is stiffened by transverse tubular members, as shown in the cut-away drawing.

Insistence on stiffness is the theme, not only of the frame, but also of the steering connections and spring mountings. The rear springs are wide and as there is only one oscillating joint the transverse rigidity is excellent. Similarly, at the front end of the car the orthodox shackle is replaced by a trunnion through which the rear end of the spring leaf passes, the centre of the spring passing through the centre of the front axle.

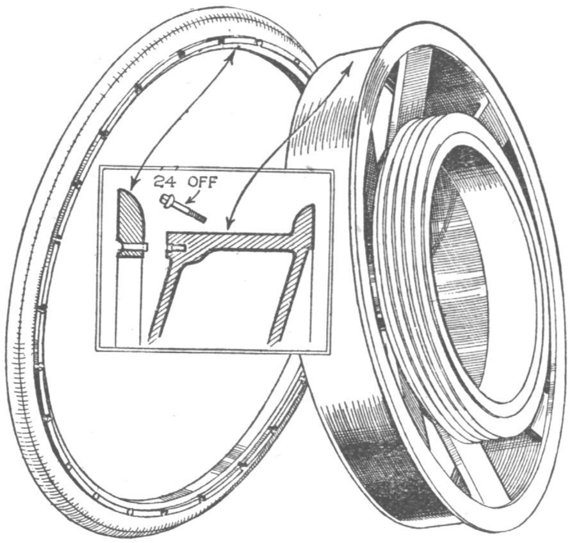
The latter is a unique design, being hollow, of double diameter and yet of single-piece construction. There is a large-section hole between the front springs and one of very much smaller diameter between the springs and the stub-axle bearing. This apparent miracle of machining was accomplished by boring the axle right through with a large-diameter drill as an initial operation, shaping it, closing up the outer portions, and then finally redrilling with a smaller diameter cutter.

Readiness to accept difficult problems of this nature has always been a particular quality of Bugatti, as can be seen from the fact that the steering arms are tapered rectangles pulled up into corresponding holes and all of them carefully shaped to a varying section, offering a resistance to deformation that accords with the load imposed.

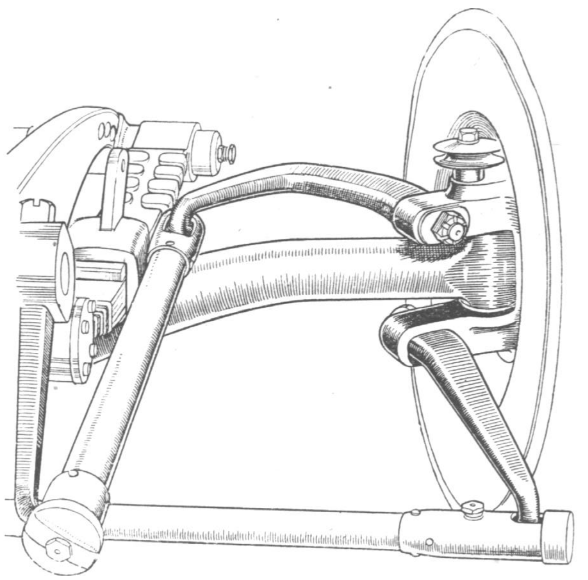
The steering box in itself contained a worm and wheel, all the moving parts running on ball bearings, and in order to prevent external loads being imposed by chance misalignment of the steering column, or following flexing of the box, a leather universal joint was incorporated in the open steering column.

The braking system was notable for direct action without servo mechanism, although a slight degree of servo action was acquired by placing the brake camshafts ahead of the centre line of the front axle together with the nearly vertical mounting of the front brake levers.

Entirely unconventional brake drums, cast integral with light alloy wheels, were introduced in 1924 and were at first a failure, as serious tyre trouble was experienced. This was due to incorrect design of the rim, and when modified no further trouble



The cast alloy wheel and brake drum in its original form with detachable rim.



The steering connections were of exceptional stiffness.

was experienced. On the later type of cars the wheels were made in one piece, but the earlier models had a detachable rim held on by twenty-four small set screws. The scheme had the merit of preventing the tyre detaching itself from the wheel whilst combining wheel and drum conferred a considerable reduction in unsprung weight. It also permitted a change of brake shoes during a race at the same time as wheels and tyres were changed.

The rear axle was an exceedingly light construction, having a two-piece aluminium alloy casting for the bevel-box, with straight-cut teeth and semi-floating half shafts running in steel tubes flanged up and bolted to the centre section. On these cars there was a choice of five final ratios giving by stages from 4.5:1 up to 3.7:1.

The gearbox in itself was remarkable for having the lay-shaft side by side with the main shaft, the depth of the box thereby being appreciably reduced.

The rear petrol tank held twenty gallons, and although the bodywork was reasonably well streamlined the driver was mounted high so as to be given maximum

control and visibility, the latter being enhanced by the narrow radiator and bonnet.

As befitted the son of an eminent artist, Ettore Bugatti always achieved good lines both in his cars as a whole and in each individual part of them. He insisted that his draughtsmen should be able to conceive three-dimensionally and draw in perspective as a prelude to laying out a part on strictly engineering lines. Many hold the view that the Type 35 Bugatti is the most characteristic representation of the normal racing car.

Supercharged to about 10 lb. per sq. in. the Type 35 engines gave about 120 horse-power in 2-litre form and between 130 and 140 horse-power in 2.3-litre guise, peak revs. being between 5,000 and 5,500 r.p.m. Sixty b.h.p. per litre is no outstanding feat for a supercharged power unit and certainly cannot be held to justify the complicated construction of the engine.

There are, however, some points to be put forward in extenuation. The design was the last but one of a series of adaptations from a prototype introduced very shortly after the 1914-18 war, and this prototype itself showed obvious signs of derivation from engines put on to the drawing board by the same hand in the 1913-14 period. Another point is that Bugatti, in this engine, clearly expressed his choice of simple machining operations backed up by highly skilled handwork in fitting and assembly, as against a type that requires a great deal of expensive tooling and jigging, but can be easily put together by ordinary labour. Finally, although the engine was of moderate output it was, when driven within the limits for which it was designed, exceedingly reliable.

The drawings show that the valves were placed vertically in the head and opened by a single camshaft operating through rocking fingers. Three valves per cylinder were used, two inlets of 0.9 in. diameter and one exhaust of 1.4 in. diameter. The lift was 7 mm., and the valves sizes, when converted into area, show clearly Bugatti's typical interest in exhaust scavenging. Whereas most racing engines have larger inlet than exhaust areas, Bugatti reversed this, the figures being 1.27 and 1.54 sq. in. per cylinder respectively. Hence, although the proportion of inlet-valve area to piston area was reasonably high (0.26), the exhaust-valve area was exceptionally large, so much so that it was necessary to open out the combustion space to allow for the valve.

Partly as a consequence of the vertical valve stems, partly because of the valve area, the cooling of the head was, to say the least, indifferent. In point of fact, there can be few successful racing engines which have run with so little water in contact with so many hot spots. The cross-section drawing shows how thin are the water spaces around

The operating mechanism of the multi-plate clutch at which the levers exert centrifugal effect that considerably augments the spring pressure.

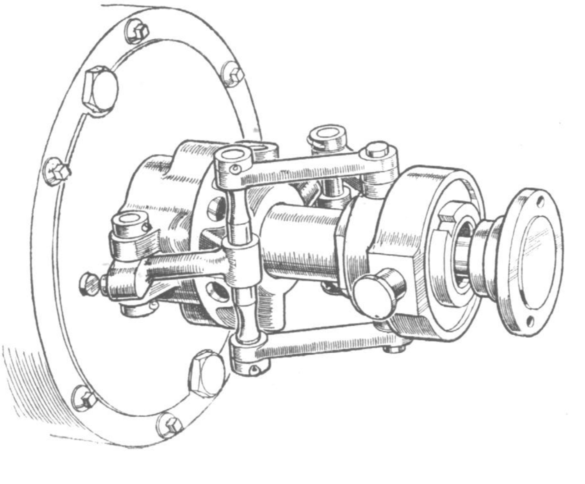


PLATE XXIII

EXAMPLE No. ELEVEN

THE Type 35 BUGATTI

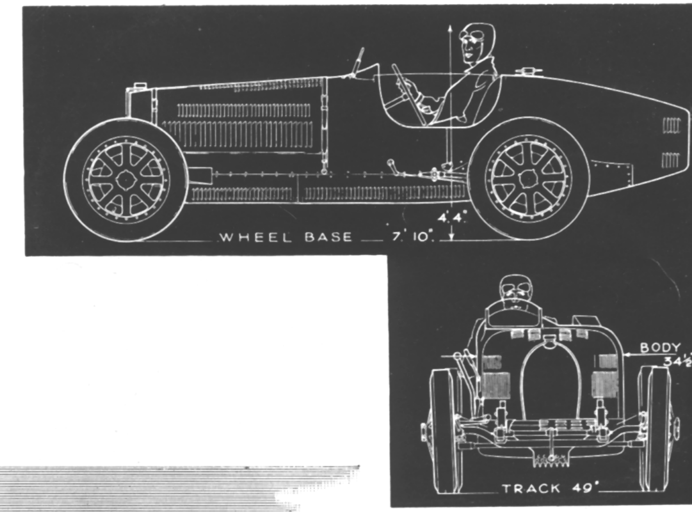
The chassis and general arrangement of this type of car were conceived and built by Ettore Bugatti for the 1924 French Grand Prix. In the following year the 2-litre eight-cylinder engine, with three vertical valves per cylinder, was improved by introducing a five-bearing crankshaft with roller bearings for main and big-ends in place of the three bearing crankshaft with white metal big-ends used previously.

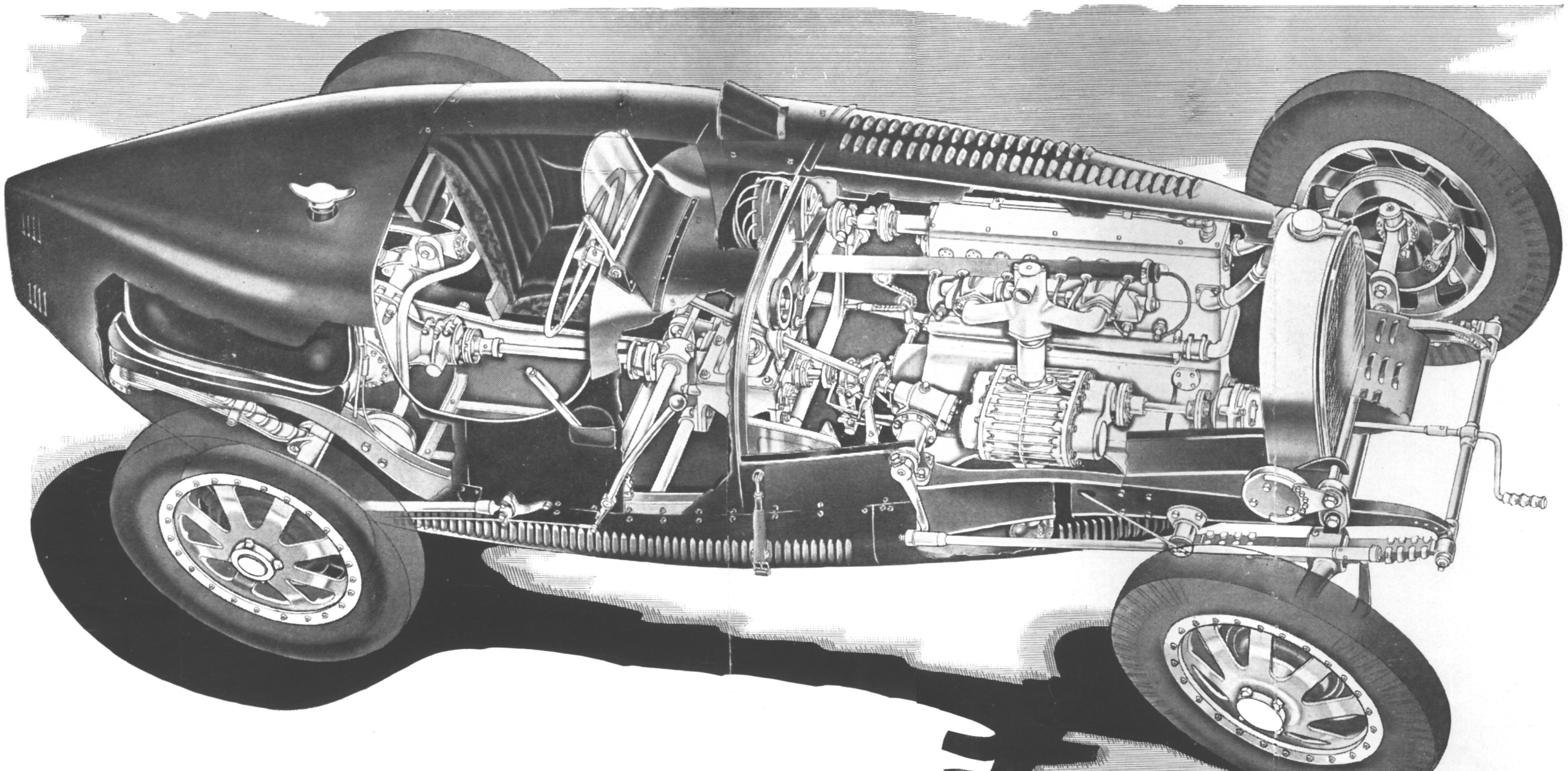
In 1926 a supercharged version was built, Type 35B, with a 2.3-litre engine and 35C with a 2-litre engine; also a variant (Type 39) with a 1½-litre engine for competition under the Grand Prix formula of 1927.

All these cars were identical with the exception of bore and stroke and supercharger size, and there was little difference in the output developed which was about 130 b.h.p.

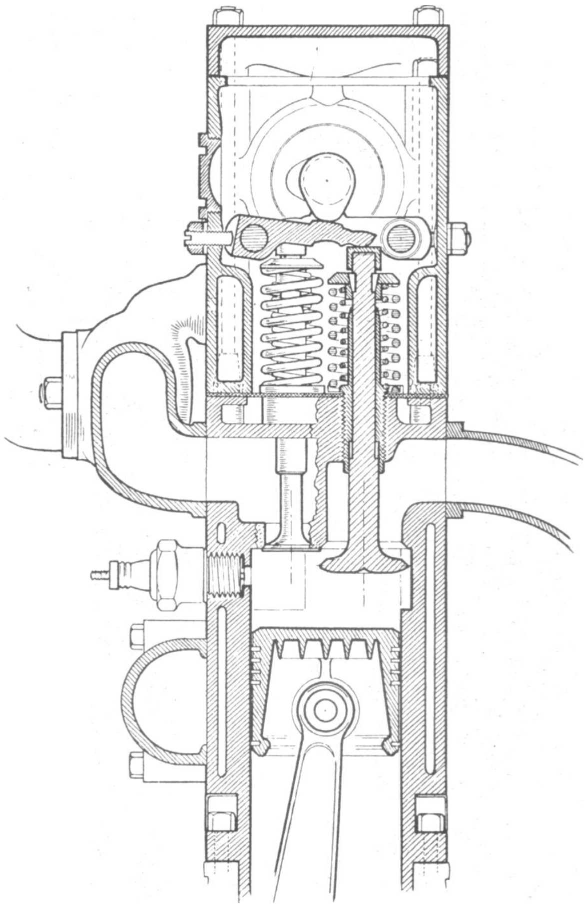
Remarkably high average speeds were secured in relation to the h.p. developed, the cars having stability and road holding far in advance of their time, which enabled them to win twenty-three races in five racing seasons. The frame side-members are developed to a depth of 7 in. in the centre part of the car, and the front part of the chassis is stiffened by bolting the sump thereto at four points. The springs were short and stiff and reverse quarter elliptics at the rear were used in conjunction with a stroke arm and outside radius arms for the rear axle.

A highly characteristic feature of this car was the aluminium wheels, which were cast in unit with the brake drums. These made it possible to change the brake shoes when changing the wheel, the brakes themselves being fully compensated but worked direct from the pedal without servo motor assistance.





the bore, and although matters are improved around the sides of the cylinder head, there is only cast-iron cooling for the important bridge which forms the adjoining sides of the inlet and of the exhaust valve seats.

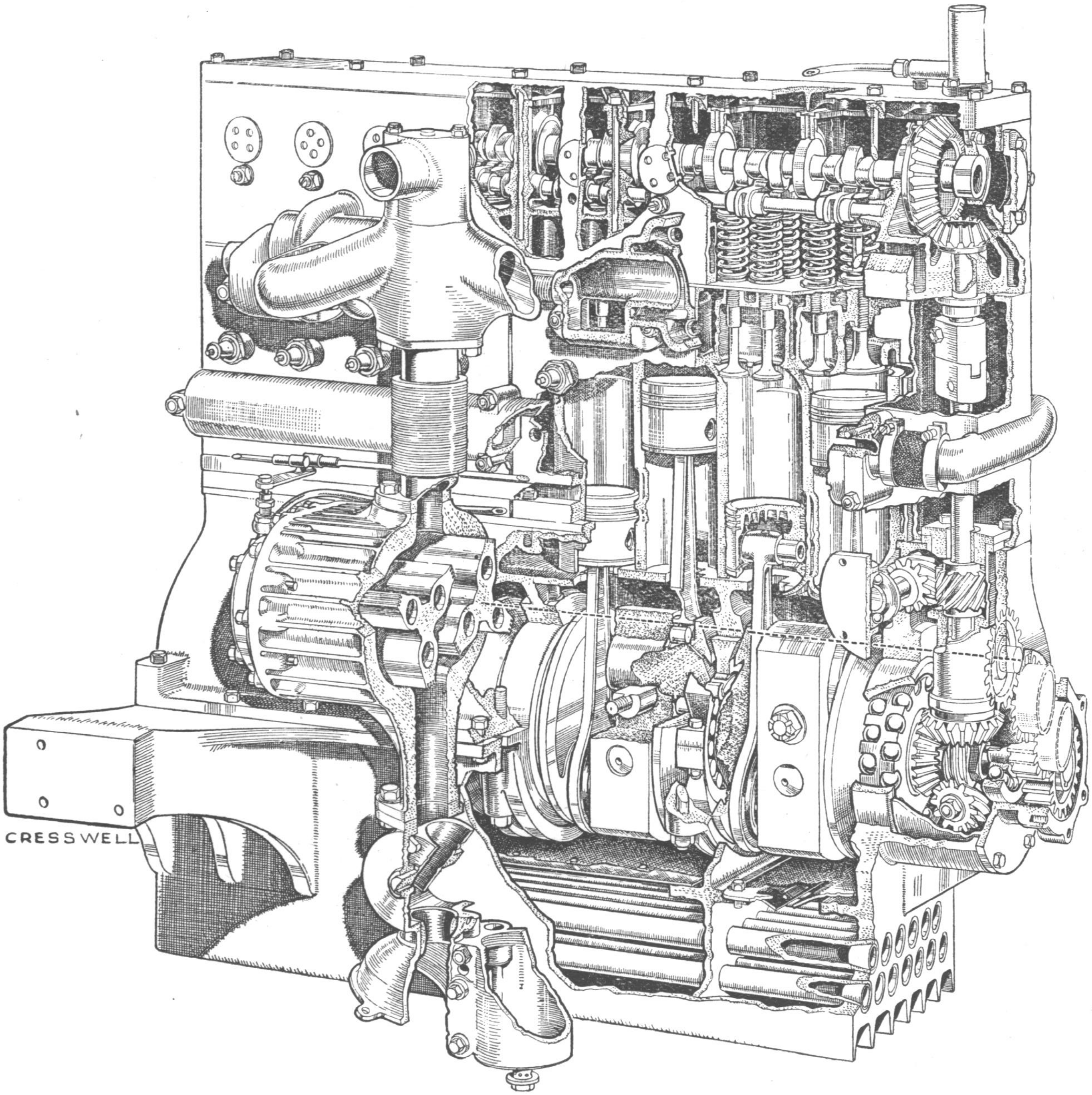


Details of valve gear and combustion chamber. (Scale 1 : 3)

Further, although the valve stems themselves were long, the valve guides were short, and the proportion of their length in contact with the water shorter still. Even the sparking plug screwed into a nearly solid mass of metal with only small water passages near to it. One interesting point should, however, be observed, which is that the top of the cylinder block was cast with an open face subsequently covered over by a thin aluminium plate which lies between the block and the camshaft housing, and forms a water seal. By this means the casting could be definitely cleaned from foundry sand and any misplaced coring would be evident.

The cylinders were cast in two blocks of four, the camshaft housing being common to all eight bores and made of light alloy with the cam running in pressure-lubricated plain bearings. Three cams per cylinder were used, clearance being adjusted by hard steel shims placed on top of the valve stems.

The bottom half of the engine had a conventional light-alloy crankcase split horizontally, but the three inner, roller, bearings were supported solely from the top half. The main journals were no less than 2½ in. diameter, and the roller bearings in which they run locked in split steel races 5½ in. diameter, these, in turn, being held to the top half of the crank by three steel straps. The outer bearings were ball type



located by both halves of the crankcase. The big ends had roller bearings, each connecting rod having seventeen rollers 7/16 in. by 7/16 in. running on a crankpin approximately 1¾ in. diameter.

The rods themselves, being made in one piece, had to be fitted on a built-up crankshaft. The centre part of this was made with two webs coupled together with taper and key. The remainder of the shaft was made by using split main bearing housings as before mentioned, and locking adjacent sections of the shaft together by pins with taper flats on them, as shown in the drawing. Obviously, the alignment of the shaft depended to a formidable degree on the skill of the workmen concerned, but, equally, the machining operations were all very straightforward.

Lubrication was not through the shaft, but by means of jets which received the oil at about 15 lb. pressure from a conventional gear-type pump and squirted it into

annular grooves around the periphery of the webs, from there to the big ends under centrifugal force.

The pistons were short and characterised by rather small gudgeon pins only 13 mm. diameter placed low down in the skirt. This permitted a wide top land and three compression rings per piston. Some engines also had an oil control ring at the base of the piston skirt.

As dry-sump lubrication was not employed, only one pump was fitted, but an attempt at oil cooling was made by using a very deep sump which not only had radiating fins on the base, but also thirteen copper tubes running fore and aft to carry cooling air right through the oil. In point of fact, this arrangement (in conjunction with the naturally high ratio of surface area of crankcase to cylinder volume on a straight-eight engine) was highly successful, and these engines would run on the track and road with moderate oil temperatures.

A train of gears at the front of the engine ran for the supercharger and a vertical drive shaft for the valve gear. The shaft turned at engine speed and a simple dog coupling allowed for engine dismantling and variations for expansion. There were two transverse drives, one for the water pump. Although the latter was mounted on the exhaust sides, for some reason the off-take from it was carried round to the inlet side of the engine where a long cast gallery supplied water to drilled holes into the cylinder block.

Typical of the designer's habit of compressing everything into the smallest space is the way in which the bottom bevel for the camshaft drive was recessed to receive the worm of the skew gear which drives the oil pump, and it will also be noted that whereas the whole of the crank assembly runs in anti-friction bearings, the camshaft mechanism utilises plain bearings.

The Roots supercharger was mounted centrally, driven at engine speed and had a three-lobed rotor. It drew mixture from a vertical carburetter and delivered through a riser pipe with T branch to two separate water-heated manifolds, one for each cylinder block. There were four inlet ports, each 1 in. by 2 in. and, of course, feeding two cylinders apiece. This layout, which involves the gas being turned through six right angles during the course of its passage from the blower to the valve head, is scarcely conducive to the utmost efficiency, but on the other hand, the scheme had a neat appearance and gave reasonably good distribution as between one cylinder and another.

The valve overlap was approximately 30 degrees, the inlet opening approximately 10 degrees before top dead centre.

By contrast with the somewhat tortuous inlet arrangements, the exhaust pipes evidence meticulous attention to gas flow. Each set of cylinders had a four-branch Y-type manifold with very easy curves bringing the gas down into a central member made of welded-up steel, which joined into a common tail pipe. This exhaust system was employed on all Bugatti cars from the earliest models up to the 3.3-litre types and was both useful and good-looking.

Both the firing order and the layout of the crankshaft were unique amongst straight-eight engines. The latter goes 1, 5, 2, 6, 3, 7, 4, 8, i.e. taking each block of cylinders separately the firing sequence is 1, 2, 3, 4 on the front four bank, and 5, 6, 7, 8 on the back four. This was coupled with a singular crank arrangement, the front half of which is shown in the cut-away drawing, the back being identical but moved through

90 degrees. In this layout the engine is well balanced except for a couple between the front and back halves of the shaft, which imposes severe loads on the centre bearing.

Ignition was by a single magneto driven from the back end of the camshaft, and although in this position the timing is affected by clearances in the gears the mechanical and electrical inertia effects in the magneto acted as a damper on torsional resilience in the camshaft itself.

As can be seen from the drawing, the sparking plugs were heavily masked, the slot being rectangular. The location of the plugs on the inlet side is one more evidence of Bugatti's talent for setting theory at naught, as the latter has always dictated a policy of firing the charge from the hot side of the head to a cool area and not, as on this engine, vice versa.

Equally unconventional was the Bugatti clutch, which was a small diameter, multi-plate type with practically no flywheel effect. The latter was not really needed on a straight-eight, high-speed engine and, in this design, the crankshaft had a considerable mass of its own. The distinctive feature of the clutch was in the operating gear. There was no means of positively disengaging the clutch plates, but movement of the pedal pushed back a swinging yoke which ran over a grooved collar. This imparted movement to a set of levers which, in turn, released pressure from two push buttons, which normally held the plates against each other.

When the clutch was engaged the pressure required to transmit the drive was provided in two ways. There was a light external spring to provide initial grip, but the main source was the centrifugal effect of the levers, which, in accordance with mathematical laws, increased the pressure applied as the square of the engine speed.

A drawing shows the mechanism partially dismantled and with the levers in an exaggeratedly elongated position.

The design of these engines was entirely characteristic of Ettore Bugatti, being unconventional in nearly every aspect, demanding the utmost in skilled workmanship and fitting, and yet, at the same time, reflecting a severe, almost brutally practical outlook, as exemplified in the locking arrangements for the crankshaft.

The Type 35 Bugatti may certainly claim to be the world's most successful racing car and as such can justifiably be taken as a norm against which prior and subsequent designs may well be compared. Certainly no other model has been capable of such wide use, that is to say for sprints, hill climbs, track racing, and road racing, and in the hands of both professional and amateur drivers, expert and not so expert.

DETAILS OF CAR

MAKE.-Bugatti
TYPE.-35B and C
YEAR OF CONSTRUCTION.-1926-30
YEARS RACED.-1926-30, by manufacturers
DESIGNER.-E. Bugatti
WHEELBASE.-7 ft. 10 in.
TRACK FRONT.-4 ft. 1 in.
TRACK REAR.-3 ft. 11 in.
HEIGHT TO SCUTTLE.-42 in.
HEIGHT TO DRIVER'S HEAD.-52 in.
FRONTAL AREA.-10.8 sq ft..
UNLADEN WEIGHT.-15.1 cwt.
ALL-UP STARTING LINE WEIGHT.-185 cwt.
MAXIMUM SPEED.-120 m.p.h.
SPEED ON INDIRECT GEARS.-100 m.p.h. on Third
" " " " 72 m.p.h. on Second
52 m.p.h. on First
H.P. PER SQ. FT.-12.2
H.P. PER TON UNLADEN.-173
H.P. PER TON ALL-up.-145
BORE.-60 mm.
STROKE.-TYPE B-100 mm.
TYPE C-88 mm.
S./B. RATIO.-B 1.67: 1
C 1.47:1
CAPACITY.-TYPE B-2,261 c.c.
TYPE C-l,955 c.c.
No. OF CYLINDERS.-Eight
PISTON AREA.-35 sq. in.
H.P.-135 at 5,300 r.p.m.
H.P. PER SQ. IN. OF PISTON AREA.-3.85
B.M.E.P.-134 lb. sq. in.
PISTON SPEED FT./MIN.-TYPE B-3,500
TYPE C-3,060
CYLINDER HEAD.-Cast-iron integral with block
VALVES No.-Two inlet, one exhaust per cylinder
VALVES ANGLE.-Vertical
VALVES AREA INLET.- 10.02 sq. in.
VALVES AREA EXHAUST.-12.3 sq. in.
CYLINDER BLOCK-Cast-iron in two blocks of four
FUEL.-Petrol, Benzole, Alcohol
CARBURETTER.-vertical Solex
SUPERCHARGER.-Three-lobed Roots with optional gear ratios
MANIFOLD PRESSURE.-10 lb. boost (1.66 atm)
IGNITION.-One magneto
PLUGS No.-Eight
PLUGS LOCATION.-Inlet side of head
CRANKCASE.-Two-piece light alloy split on centre line with bottom half carrying engine bearers
CRANKSHAFT.-Built-Up counterbalanced
MAIN BEARING No.-Five
MAIN BEARING TYPE.-Ball and roller
BIG END TYPE-Roller with one-piece big ends
LUBRICATION.-wet Sump
CAMSHAFT No.-One
CAMSHAFT LOCATION.-In head
CAMSHAFT DRIVE.-Vertical shaft and bevel gears
CAMSHAFT DRIVE LOCATION.-Front of crank
CLUTCH.-Multi-plate with centrifugal servo assistance
GEARBOX LOCATION.-Separate from engine
GEAR RATIOS.-3.6 (optional ratios 3.37 highest, 4.5 lowest), 4.7, 6.65, 8.72
TRANSMISSION.-open propeller shaft to bevel drive rear axle
FRAME.-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Splayed reverse quarter-elliptic
SHOCK ABSORBER TYPE.-Bugatti friction
BRAKE SYSTEM.-Mechanical ; foot, through differential compensator to all four wheels ; hand, to rear wheels
BRAKE DRUM DIAMETER.-Drums integral with wheels 11 in. internal diameter
BRAKE DRUM WIDTH.-2 in.
SQ. IN. PER TON LADEN.-294 sq. in.
STEERING.-Worm and wheel, 1 turn lock to lock
WHEELS.-Bugatti patent, light alloy castings
TYRES.-Dunlop, 29 x 5.00 for special rim, front and rear

RACING RECORD-TYPE 35B-2.3-LITRE

Date	*Event*	*Course*	*Average Speed*	*Lap Speed*
25/4/26	Targa Florio . . .	Short Madonie	45.68 m.p.h.	46.8 m.p.h.
12/6/27	Rome G.P.	Trefontana	68.88 m.p.h.	—
14/8/27	Coppa Ciano..	Montenero	50.14 m.p.h.	
6/5/28	Targa Florio	Short Madonie	45.65 m.p.h.	46.2 m.p.h.
22/4/28	Alessandria G.P. . . .	Alessandria	63.45 m.p.h.	66.5 m.p.h.
5/7/28	Marne G.P.	Rheims	82.49 m.p.h.	91.4 m.p.h.
15/9/29	Monaco	Monaco	49.83 m.p.h.	—

TYPE 35C-2-LITRE

Date	*Event*	*Course*	*Average Speed*	*Lap Speed*
24/4127	Targa Florio . . :.	Short Madonie	44.61 m.p.h.	46.6 m.p.h.
9/9/28	Italian G.P. . .	Monza	99.14 m.p.h.	102.8 m.p.h.
3/6/28	Tunis G.P.	Bardo	*75.6* m.p.h.	77.85 m.p.h.
10/6/28	Rome G.P.	Trefontana	78.55 m.p.h.	80.4 m.p.h.
28/7/28	San Sebastian . . .	San Sebastian	80.58 m.p.h.	88.25 m.p.h.
5/5/29	Targa Florio .	Short Madonie	46.21 m.p.h.	47.3 m.p.h.
30/6/29	French G.P. . .	Le Mans	82.66 m.p.h.	—
14/7/29	German G.P. .	Nürburg	66.79 m.p.h.	69.97 m.p.h.
20/7/30	Eifel Races .	Nürburg	68.04 m.p.h.	—
21/9/30	French G.P.	Pau	90.4 m.p.h.	—
6/4/30	Monaco . .	Monaco	54.63 m.p.h.	56.01 m.p.h.
20/7/30	European G.P.	Spa	72.1 m.p.h.	—

Also many other wins with works-entered cars (and by private owners) in races of less than Grand Prix status or on circuits not used subsequently.

EXAMPLE No. TWELVE

The 4.5-Litre Bentley

IN periods of technical weakness it becomes possible for the series type high-performance car to compete with, and on occasions beat, the pure racing design.

It has been recorded elsewhere that the years 1928-31 constituted such a period, and it is, therefore, not inappropriate to include amongst the examples of Grand Prix cars a catalogue model which was originally designed for sports car racing and only found itself in a Grand Prix event by the accident of fate.

Such a one was the 4½-litre supercharged Bentley, which achieved second place in the French Grand Prix of 1930 when driven by Sir Henry Birkin, Bart. In this event he was beaten by a Type 35C Bugatti, but in turn was faster than a large number of these and other racing cars.

The 4½-litre Bentley was a direct development and enlargement of a 3-litre model produced in 1920 which was in turn largely inspired by the 1914 Grand Prix racing cars.

The original design had cylinders measuring 80 mm. x 149 mm., and the larger type was a scaled-up version with dimensions 100 x 140 mm. The 4½-litre was produced largely with an eye to the Le Mans twenty-four-hour race and was entered for this event in 1927. The following year the type won the event, and in 1929 it obtained second, third and fourth places behind a 6½-litre six-cylinder Bentley, which came home first by a margin of seventy-two miles.

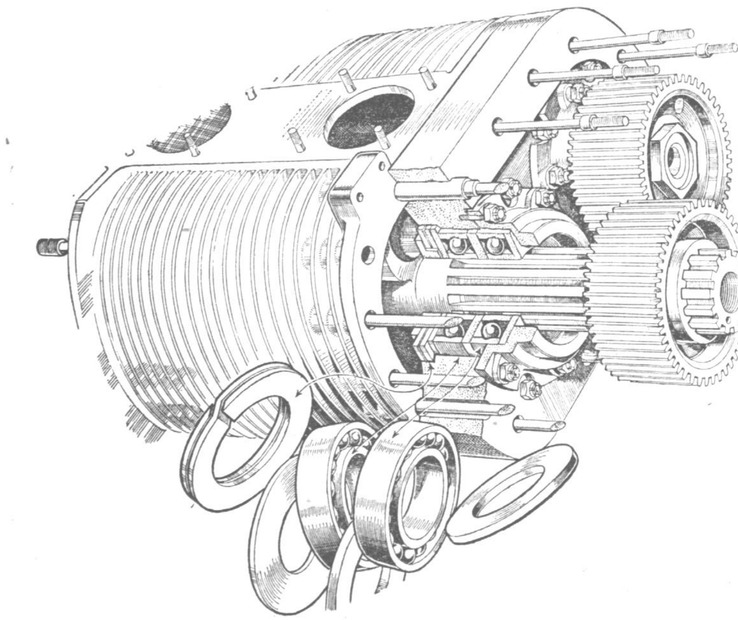
The reliability of the larger car made it the choice of Mr. W. O. Bentley and his technical associates for the subsequent events in which his company was interested, but Sir H. R. S. Birkin, advised by Mr. Amherst Villiers, was of the opinion that even better results could be obtained by supercharging the 4½-litre. It was realised that considerable modifications would have to be made to the engine if reliability were to be obtained, but finance being forthcoming, the necessary work was started privately by Birkin to Villiers' designs in the winter of 1928-9, and the car made its debut in the Irish Grand Prix of the latter year.

A Roots-type blower, having a capacity of 5.6 litres, was driven from the front end of the crankshaft and mounted between the front dumb-irons. Three cars were prepared for racing, two with a wheelbase of 10 ft. 10 in., and one with a wheelbase of 9 ft. 10 in. The bodies had, of course, to comply with the Le Mans and other regulations of the time governing sports car races, and this, in conjunction with the long stroke of the engine and the high side-members of the frame, of necessity resulted in a large frontal area. Running stripped as in the French Grand Prix, the frontal area amounted to approximately 17 sq. ft., whilst with head lamps, mudguards added, this figure would increase to approximately 19 sq. ft.

The standard engine in unblown form developed 125 h.p. at 3,500 r.p.m., and supercharging increased this by 80 per cent, so that approximately 240 h.p. was realised at 4,200 r.p.m. By calculation this power is sufficient to drive the car at 125 m.p.h., and on the top gear used (3.0 to 1) this speed would be equivalent, neglecting wheel spin, to 3,900 r.p.m.

No positively accurate information is available concerning the maximum speed of this car on the road, but Sir Henry Birkin claims to have reached 135 m.p.h. at Pau. This would imply over 4,000 r.p.m. on the engine and, on theoretical grounds, a higher h.p. than it is known to have developed. A similar car has, however, lapped Brooklands at 127 m.p.h. and on balance of evidence therefore a maximum road speed of 130 m.p.h. is acceptable.

It will be seen on a maximum speed basis the Bentley was the equal of the racing Type 35 B and C Bugattis, but it was handicapped by great weight, the figure for



The Roots type blower, giving a boost of circa 12 lb., employed exceptionally wide gears and an ingenious method of scaling the rotor shafts.

the short-chassis car in racing trim being about 38 cwt. bare, and 41.5 cwt. one up plus fuel, etc. Thus the b.h.p. per ton is figured distinctly unfavourable as compared with cars designed and built specifically for Grand Prix racing.

This handicap also extends to the braking system, despite the use of drums nearly 16 in. in diameter.

The general features of the design are vividly portrayed in the sectionalised drawing and one should note that engine construction largely determined the aspect of the whole car. The comparatively long stroke and the employment of a single overhead camshaft inevitably gave a considerable height from the top face of the crankcase to the camshaft cover, and thus imposed a comparatively high radiator and dashboard assembly. The choice by the designer of wet-sump lubrication employing large oil capacity, and, therefore, a deep base to the crankcase, brought the centre line of the crank high from the ground and necessitated a wheel of 16 in. radius. Thus the engine design is primarily responsible for the frame being 2 ft. off the ground, and for the driver's head being 63 in. above the ground.

The high centre of gravity of the Bentley forced the use of stiff and heavily damped springs in order to prevent excessive roll on corners. The drawings show that double Hartford shock absorbers were used at the back, and that all four semi-elliptic springs were closely bound, in addition to being fitted with U-section clamps.

Stiffness of springing was also imposed by the considerable unsprung masses, the rear axle in particular being abnormally large and heavy, whilst the use of large-diameter

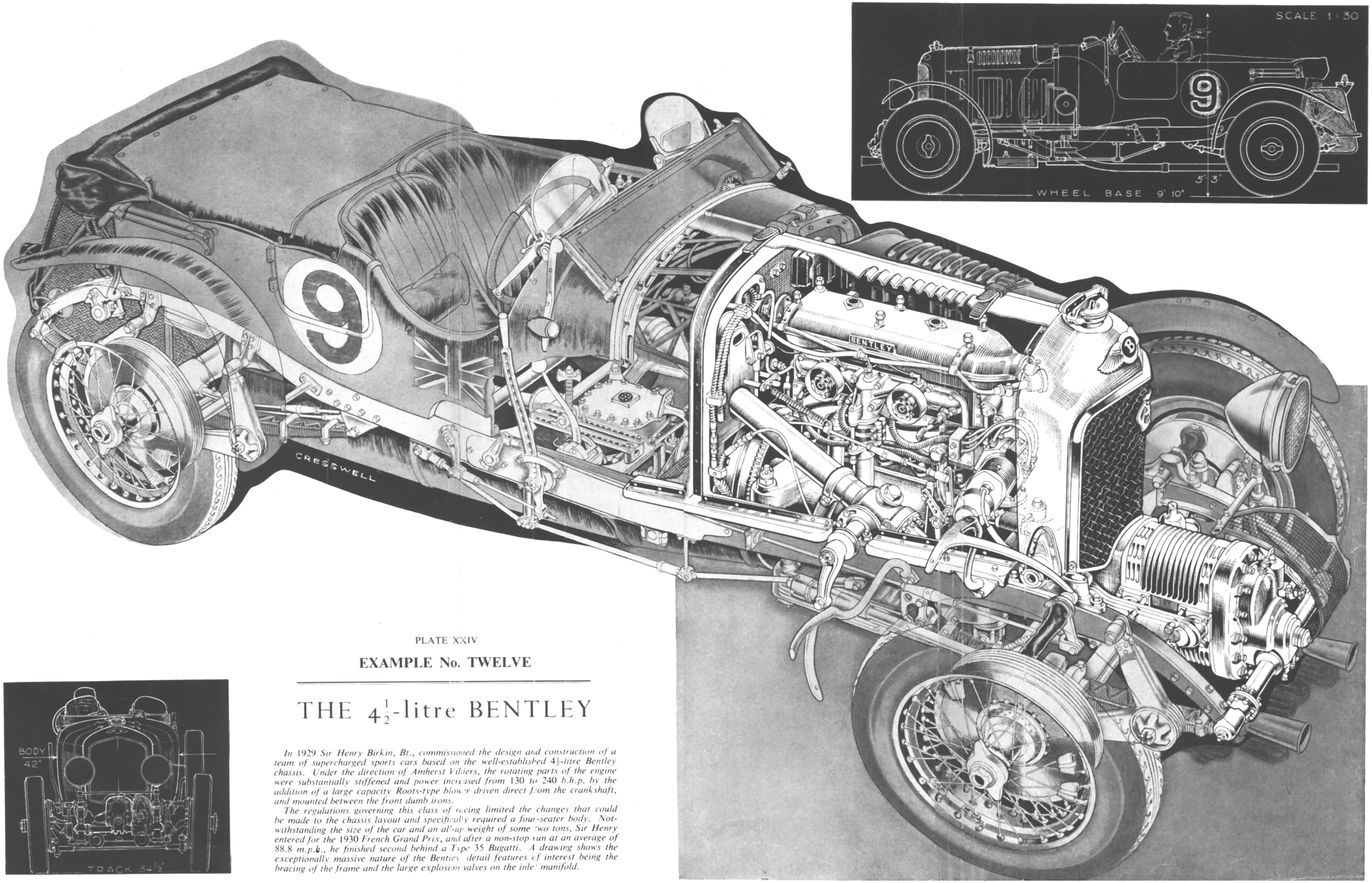


PLATE XXIV

EXAMPLE No. TWELVE

THE $4\frac{1}{2}$-litre BENTLEY

In 1929 Sir Henry Birkin, Bt., commissioned the design and construction of a team of supercharged sports cars based on the well-established $4\frac{1}{2}$-litre Bentley chassis. Under the direction of Amherst Villiers, the rotating parts of the engine were substantially stiffened and power increased from 130 to 240 b.h.p. by the addition of a large capacity Roots-type blower driven direct from the crankshaft, and mounted between the front dumb irons.

The regulations governing this class of racing limited the changes that could be made to the chassis layout and specifically required a four-seater body. Notwithstanding the size of the car and an all-up weight of some two tons, Sir Henry entered for the 1930 French Grand Prix, and after a non-stop run at an average of 88.8 m.p.h., he finished second behind a Type 35 Bugatti. A drawing shows the exceptionally massive nature of the Bentley detail features of interest being the bracing of the frame and the large explosion valves on the inlet manifold.

cast-iron brake drums added to the problem, which, however, was mitigated by the considerable sprung mass of the car, for it must be remembered that the criterion is not the unsprung weight, but the ratio of sprung to unsprung masses.

The gross weight, well over 2 tons with driver and fuel aboard, must make the Bentley the heaviest car ever to compete in a Grand Prix race. Much attention was given to reducing the weight of detail parts by drilling, but there was a large amount of heavy equipment, the large filler caps and outsize fuel tank, for instance. Inspection of the car shows that many components are unnecessarily, even absurdly, heavy.

The frame was of conventional design, of U-section with tubular bracing at the front of the dumb-irons, and just under the driver's seat. Being only 4 in. deep, it was not surprising that it was found to have inadequate beam stiffness, and to overcome this a cantilever arrangement of bars was bolted to the under section, a feature which effected improvement, although, of course, it left the torsional stiffness virtually unchanged. All connections in the frame were by high-tensile bolts exactly fitted into hand-reamered holes.

The engine was bolted direct to the side-members, the gearbox being separately locked on a small sub-frame assembly. The standard D-type Bentley gear ratios were employed, but the gear pinions were cut with especially coarse teeth. There can be no doubt that the closeness of the indirect ratios, and the high speeds obtainable on all of them, were a considerable help in maintaining performance on road circuits.

The clutch was an orthodox single-plate type, and power transmitted from the gearbox by a Hotchkiss drive system employing pot-type universal joints, an interesting legacy from the 1914 T.T. Humber designed by Mr. Burgess, who assisted W. O. Bentley in the layout of these cars.

The steering mechanism calls for little notice, being worm and wheel, with 1-7/8 turns from lock to lock.

The complete absence of streamlining, or any attempt towards it, is largely explained by the necessity of building the car according to regulations, which prescribed a four-seater body having minimum dimensions, and also carrying lamps and mudguards. A hood was also required by the Le Mans authorities, and hence the designer could exercise little initiative in these directions. It is worth remembering that the regulations regarding passenger accommodation at Le Mans have in more recent years been considerably relaxed and the aerodynamic opportunities now available were not present when this car was designed.

At the back of the body a large fuel tank with a capacity of approximately forty-five gallons gave a range at, say, 8 m.p.g., of 360 miles without refuelling. Various fuels were tried on these engines, ranging from pure benzole to approximately 30/70 petrol:benzole mixture.

It will be seen that both the fuel tank and the radiator have cam-type, quick-opening fillers, and it is worth putting on record that the Bentley Company were amongst the pioneers of these fittings, which have obvious advantages over the screw-type filler caps which had been previously employed on all racing cars. Both the radiator and the rear tank were fully protected from flying stones, a necessary feature at a time when road surfaces were liable to break up during the course of a twenty-four-hour event.

By modern standards the fuel lines from tank to carburetter seem unduly small but the flow was, of course, calculated for petrol/benzole mixture and not for alcohol

blends, which make far greater demands on the system. Air pressure was employed to force fuel from the tank to the supercharger.

The last-named component was of Roots form, but as designed by Amherst Villiers, embodying many detail refinements.

As shown in a drawing the gears connecting the rotor were of exceptional width and had special means to ensure accurate meshing of the teeth in relation to the relative position of the rotors. The latter were in one with the steel shafts which ran on two ballbearings at each end with an ingenious metal seal which, again, is the subject of a detail sketch. The blower had two induction ports in an exceptionally deeply ribbed case. The prototype blower case had, in fact, been water cooled, but difficulties were experienced with keeping the water connections tight and in avoiding porosity in the casing, and this particular project was therefore abandoned. The blower was mounted ahead of the radiator and driven directly from the nose of the crankshaft and aspired mixture from two S.U. carburetters of the constant vacuum type.

On the pressure side of the system particular care was given to the design of the two explosion valves. Due to the length of the inlet pipe a considerable volume of gas was present and in the early development work it was found that if the release valve spring was too heavy the pipe connections failed to withstand the explosion loads ; if too light the valve might stick open and a stream of constantly burning gas would emerge.

The attention given to the induction system was scarcely matched by the exhaust arrangements which included a number of abrupt bends very close to the valve ports.

Two inlet and two exhaust valves per cylinder were used, being inclined in the fixed cylinder head at approximately 60 degrees. The valve gear betrays obvious signs of derivation from 1914 racing car practice, being virtually an enclosed version of the scheme used on the winning Mercedes car, that is to say a single camshaft driven by bevels and vertical shaft which works the valves through rockers, there being one inlet cam connecting to a forked rocker and two exhaust cams. The camshaft ran in a tunnel through which the rockers emerged, but whereas on the Mercedes the outer end of the latter, and the valve springs, were exposed, on the Bentley the whole mechanism was enclosed in an aluminium cover.

Additionally, on the Bentley the vertical shaft was at the front end of the engine together with a right-angle drive connecting the two magnetos.

Two sparking plugs per cylinder were fitted horizontally on opposite sides of the head. In the Bentley the cylinder block is a single iron casting, open at the sides, where it was closed by a sheet of light alloy. Water circulation was by means of a large centrifugal pump driven from the nose of the timing mechanism, the water being led somewhat surprisingly to the base of the inlet side of the block and emerging through five separate branch pipes immediately above the exhaust manifold.

The crankcase was formed from two exceptionally deep light-alloy castings which are split on the centre line of the five main bearings. On the blower car both crankshaft and bearings were specially designed by Amherst Villiers. The former was particularly massive, the main bearings being of 80 mm. diameter and the big ends 55 mm. diameter, whilst exceptionally deep and stiff bearing caps were used.

The connecting rods, also, were of special design joined to concave light-alloy pistons with deep concave heads giving a low nominal compression ratio of 5:l.

The piston design was, of course, determined by the sports car regulations for which the car was primarily designed. These forbade the use of alcohol fuel, and as with 12 lb. boost a 5:l compression ratio is the equivalent of 6.5:1, from a detonation viewpoint the figure was reasonable when running on petrol/benzole mixture.

It is worth noting that the m.e.p. and h.p. per sq. in. developed by this engine were equal to any full racing car built between 1927 and 1932.

From a power per litre standpoint the engine was, of course, completely compromised by inadequate piston area and it also suffered from certain detail defects, notably a tendency to crack the cylinder head on the exhaust side if run for prolonged periods on full throttle.

The comparative success of the Bentley in competition with the purely racing types of its own era, the spectacular feats of driving by Birkin, and the magnificent and imposing appearance of these cars, have all contributed to give them a heroic and legendary fame in England. This is by no means undeserved, but from the viewpoint of sober technical narrative, one must not forget that their successes at the time were partially due to the comparatively inferior performance of the contemporary racing cars.

DETAILS OF CAR

MAKE.-Bentley
TYPE.-Supercharged 4½ litre
YEAR OF CONSTRUCTION.-1929
YEARS RACED.-1929, 1930
DESIGNERS.-W . O. Bentley, Amherst Villiers
WHEELBASE.-9 ft. 10 in.
TRACK FRONT.-4 ft. 6½ in.
TRACK REAR.-4 ft. 6½ in.
HEIGHT TO SCUTTLE.-55 in.
HEIGHT TO DRIVER'S HEAD.-63 in.
FRONTAL AREA.-17 sq. ft.
UNLADEN WEIGHT.-38 cwt.
ALL-UP STARTING LINE WEIGHT.-41.5 cwt.
MAXIMUM SPEED.-130 m.p.h.
SPEED ON INDIRECT GEARS.-100 m.p.h. on Third
" " " " 80 m.p.h. on Second
50 m.p.h. on First
H.P. PER SQ.FT.-14.2
H.P. PER TON UNLADEN.-126
H.P. PER TON ALL-UP.-116
BORE.-100 mm.
STROKE.-140 mm.
S./B. RATIO.-1.4:1
NO. OF CYLINDERS.-Four
CAPACITY.-4,486 c.c.
PISTON AREA.-48.5 sq. in.
B.H.P.-240 at 4,200 r.p.m.
H.P. PER SQ. IN.-4.95
B.M.E.P.-165 lb. sq. in.
PJSTON SPEED FT./MIN.-3,860
CYLINDER HEAD.-Cast-iron integral with block
VALVES NO.-Four per cylinder
VALVES ANGLE.-60 degrees
VALVE AREA INLET.-13.6 sq. in.
VALVE AREA EXHAUST.-13.6 sq. in.
CYLINDER BLOCK.-Cast-iron in one block

FUEL.-Petrol, Benzole
CARBURETTER.-Two S.U. horizontal
SUPERCHARGER.-Roots at engine speed
MANIFOLD PRESSURE.-12 lb. boost (1.82 ata)
IGNITION.-Two Bosch Magnetos
PLUGS NO.-Eight
PLUGS LOCATION.-Horizontally opposed sides of the head
CRANKCASE.-Two-piece light alloy split on bearing centre line
CRANKSHAFT.-One-piece counterbalanced
MAIN BEARING NO.-Five
MAIN BEARING TYPE.-White metal
BIG END TYPE.-White metal
LUBRICATION.-Wet Sump ; I
CAMSHAFT NO.-One
CAMSHAFT LOCATION.-In head
CAMSHAFT DRIVE.-Vertical shaft with bevel gears
CAMSHAFT DRIVE LOCATION.-Front of crank
CLUTCH.-Single plate
GEARBOX LOCATION.-Separate from engine
GEAR RATIOS.- 3, 4.05, 4.95, 8:l
TRANSMISSION.-Open propeller shaft to bevel drive rear axle
FRAME.-Channel
FRONT SUSPENSION.-Semi-elliptic
REAR SUSPENSION.-Semi-elliptic
SHOCK ABSORBER.-Hartford friction
BRAKE SYSTEM.-Mechanical ; foot, to all four drums, hand to rear wheels
BRAKE DRUM DIAMETER. 15.75 in. front and rear
BRAKE DRUM WIDTH.-2 in. front and rear
SQ. INS. PER TON LADEN.-193
STEERING.-Worm and wheel 1-7/8 turns lock to lock
WHEELS.-Rudge-Whitworth detachable
TYRES.-Dunlop 6.00 x 21, front and rear

EXAMPLE No. THIRTEEN

The P3 Alfa-Romeo

IN the five years 1924-29 the celebrated 2-litre straight-eight Alfa Romeo Type P2 had had the engine output raised from about 130 b.h.p. to nearly 170 b.h.p. with an associate step up in maximum speed from circa 125 m.p.h. to 140 m.p.h. At these higher rates of speed the chassis was found to be seriously defective and in 1930 it was being beaten by cars of lesser power output but with better road holding.

In 1931, after seven years of racing life, it was therefore retired and its place taken by two cars, both developed from the 1,750 c.c. six-cylinder supercharged sports cars which the Company was then making as a catalogue model and running with great success in sports car races. One of the new cars was fitted with an engine having the same bore and stroke as the sports model (65 x 88 mm.) but with eight cylinders in line in place of six giving a capacity of 2.3 litres and an output of some 160 b.h.p. This car was called the " Monza " and the most notable feature of the engine was the use of two blocks, each with four cylinders, and a two-piece crankshaft with a train of gears placed in the centre of the engine and driving two overhead camshafts and a single blower on the right-hand side of the car.

An alternative model embodied the bold concept of fitting two six-cylinder 1,750 c.c. engines and gearboxes in one chassis. There had in the past been instances of engines with double crankshafts which were normally geared together, but in the Alfa Romeo the units were quite separate, both as to crankcase and gearbox, and also in respect of the propeller shaft, crown-wheel and pinion. There were also two gear levers connected together and these gave the driver the option of left- or right-hand changing for he sat centrally in the car.

This literal twin-six car was, in fact, the first Monoposto to run in European G.P. racing, although Bugatti built a team of such cars for 1,100 c.c. racing in 1926, and there were also the modified American track racing cars which ran at Monza in 1927. Despite being handled by well-known drivers such as Nuvolari, this car was not a successful type, one of its defects being a high unladen weight amounting to 23 cwt. On the other hand, the Monza type was reasonably successful, but with about the same output as obtained on the P2 it was never able decisively to compete with the Type 51 Bugattis and the corresponding Maserati cars. Alfa Romeo, therefore, decided to introduce another car, the P3, in which the best points of both the 1931 models would be reproduced. The engine was an enlarged edition of the immediately preceding eight-cylinder, bore being increased to 65 mm. and stroke to 100 mm., giving an engine capacity of 2.65 litres. The same general layout was employed but with inlet and exhaust systems reversed and two blowers placed on the near or left-hand side of the car. The driver was mounted centrally behind the engine and it was the P3 which became known to the world as the Monoposto and achieved world-wide fame by an almost absolute mastery of road-racing circuits in events for which it was entered.

In detail, the cars were run in six events in 1932, of which they won four, were beaten by an accident of lap counting in one and by reason of mechanical defects in the other. In 1933 they ran in two races and won both.

This finished the life of the P3 as originally designed. In 1934 it became the P3 Type B, with the chassis enlarged by adding to both wheelbase and track, and with the engine capacity increased to 2.9 litres by boring out the cylinders to 69 mm. In this form it won the Monaco and French Grands Prix 1934, and a large number of minor races in this and subsequent years. This description is restricted to the car in its original form.

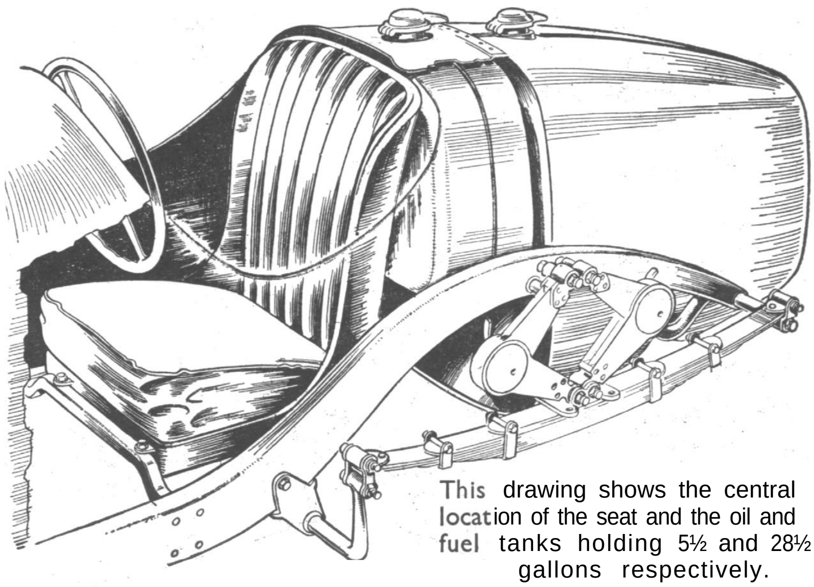
Probably the most striking feature is the exceptionally low weight. The car was officially weighed-in to race at 15.2 cwt., and as low as 14 cwt. was claimed for it in completely stripped condition. This is an altogether exceptionally low figure, both in relation to the wheelbase and the engine size, and everywhere one studies the design, it is evident that power to weight ratio and the acceleration were uppermost in the designer's mind, with maximum power and top speed a secondary consideration. The unique transmission system undoubtedly contributed materially towards weight reduction, as well as having certain other advantages.

Reference to drawings shows that two propeller shafts were used, the torque being divided immediately behind the gearbox and power transmitted to two bevel boxes, one at each end of the axle beam.

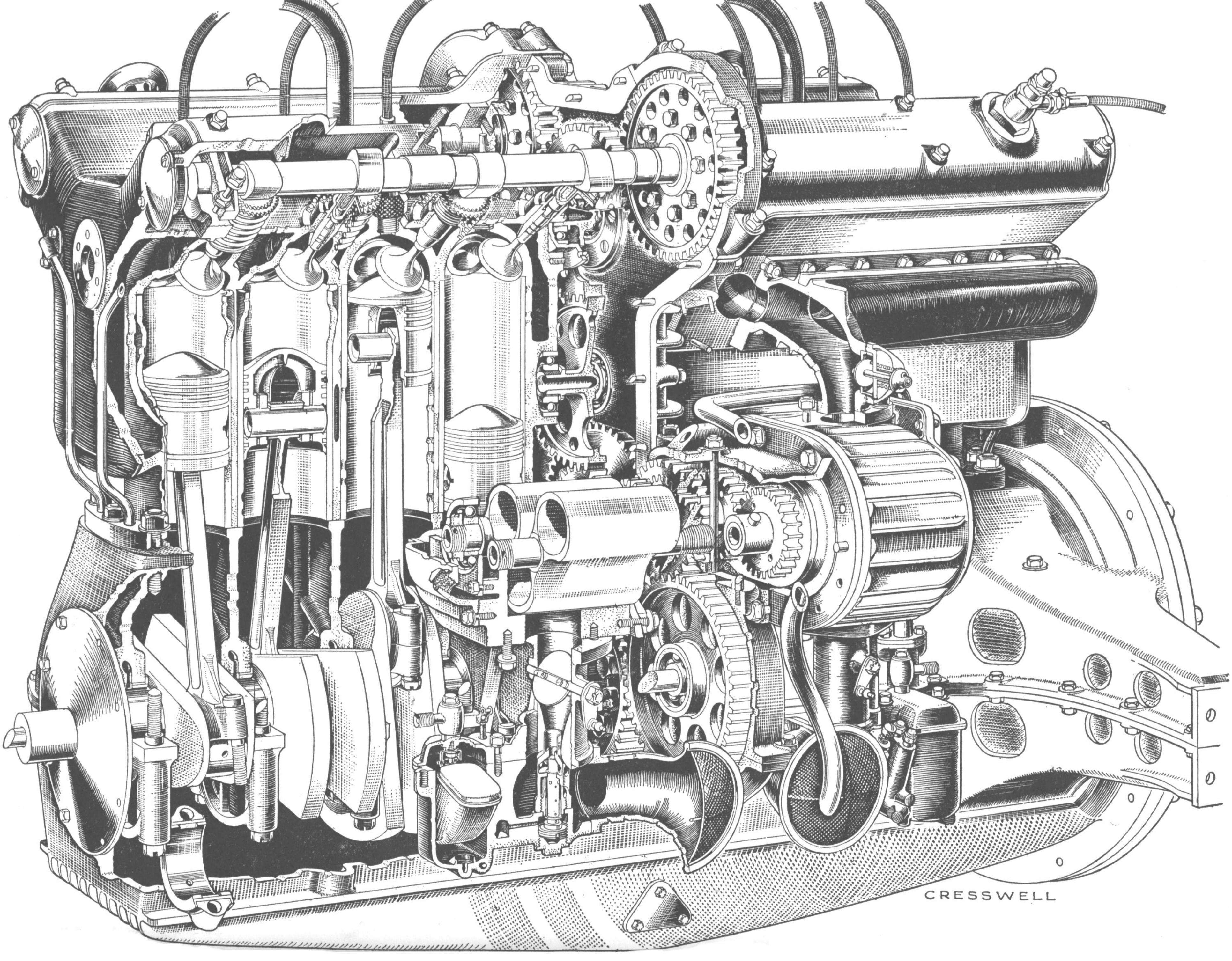
A normal live rear axle has a considerable weight and it is also weak as a beam if it is used to transmit the tractive effort of the road wheels to a central torque tube. With the triangulated design used on the P3 the heavy centre of the normal axle has been replaced by a light-steel tube and the two light-alloy bevel housings do not have to embrace a differential gear ; each pair of bevels has to transmit only half the total torque.

The " half" shafts were, in fact, no more than stubs and this again showed a useful reduction in weight. Moreover, as the differential unit was placed before the final gear reduction, this in turn can be much lighter than normal and, in addition, can be reasonably regarded as sprung weight.

A drawing shows the schematic layout and it should be noted that the first stage gears could be changed and the overall ratios from engine to rear wheels correspondingly varied without dismantling the rear axle. The latter contained two alternative crown-



This drawing shows the central location of the seat and the oil and fuel tanks holding 5½ and 28½ gallons respectively.

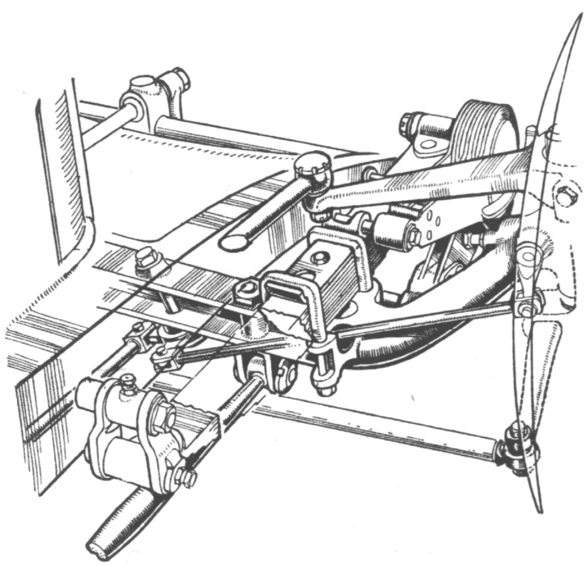

CRESSWELL

wheels and pinions offering either 10.33 or 11.36, and there were a number of possible choices, first stage gears varying between 23.31 and 27.27. On the lowest ratio 5,400 r.p.m. equalled 104 m.p.h. with the smallest size of tyre. On the highest gear with the largest possible tyre 150 m.p.h. is theoretically available at the same engine speed.

The whole of this rear axle and torque tube assembly was mounted on semi-elliptic springs, shackled at both ends. These were mounted on outriggers as the frame had the same width as the body, that is, only 26 in. to the outside of the channel. The rear of the back springs was mounted directly on an extension of a cross-tube, which braced the chassis transversely ; at the front, a separate bar cranked through a right angle was led through the shackle.

The side rails of the frame were 5 in. deep and were somewhat meagrely cross-braced, but at the front of the car torsional stiffness was improved by the rigid four-point mounting of the engine. There was also a small diameter tube between the extreme front of the dumb-irons. Behind the engine, however, the frame had only three small diameter cross-tubes, the effectiveness of two of which was lessened by their being cranked.

The semi-elliptic front springs also were shackled at both ends, the axle being located by two radius arms attached below the H-section axle beam and set inside the springs. The axle was, therefore, prevented from turning when the front brakes were applied. The worm and wheel steering box was mounted centrally behind the cylinder block, a short extension leading to the long drop of the arm mounted on the right-hand side of the car, which connected to the steering arms through an unusually long push-pull rod. The result, of course, was a considerable discrepancy between the arc struck by this steering rod and that imposed upon the axle by the much shorter radius rods, the effects, however, being mitigated by the limited vertical motion permitted on the front wheels.



The arrangement of the front axle radius arm which is in compression during braking can be seen in this detail drawing.

The front axle was conventional and pierced on each side between the spring pads to permit the passage of brake rods. By a system of bell cranks, this moved another

rod (threaded to provide adjustment) through the hollow king pin, and the layout, therefore, was unaffected by angular motions of the road wheels. A conventional arm worked an ordinary cam to expand the shoes both front and back. The linings were Ferodo M.R.

The Alfa has a perfectly straightforward mechanical linkage, employing rods throughout, and, in view of the inherently low mechanical efficiency, the ratio between pedal travel and shoe travel had to be such that comparatively slight wear in the brakes brought the pedal to the limit of its travel. The adjustment was accessible so that the brakes could be taken up during a pit stop but the cars were normally driven by Continental drivers of great experience, whose cornering technique was such that comparatively little braking was needed.

The springs themselves were provided with a number of clips and had a considerable number of leaves, the shock absorbers being applied direct to the locating plates embraced by the U-bolts attaching them to the axles. The shackles were short and stiff and gave good sideways location.

Rapid adjustment was also provided for the friction shock absorbers, a single pair being used at the front and a double set at the rear.

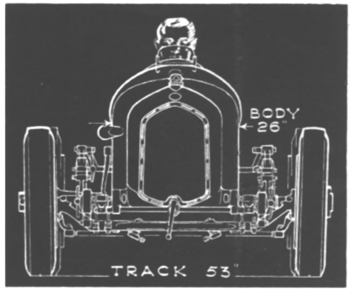
As shown in a separate drawing, the fuel tank constituted the rear half of the body and held approximately twenty-eight gallons, being preceded by an oil tank holding rather over five gallons. No really serious effort was made in streamlining, although the body (on the 1932-3 models) was kept down to frame width and a reasonable profile was, all things considered, maintained.

The gear gate and lever came up between the driver's legs, the clutch pedal being mounted on the left of the gearbox and the brake pedal on the right thereof, with the accelerator pedal on the extreme right. The driving position was high relative, not only to the road, but also to the pedals, which gave a comfortable position, and there was ample elbow room for the driver even with the narrow body first fitted. The height of the seat was, of course, a consequence of the central position, for the use of two propeller shafts does not lessen the need for clearance above the torque tube in the full bump position. It will be appreciated that the seat lay across the apex of the V and that any practical advantage on the score of height could only be obtained if the rear axle had cleared the squab, with the two other sides of sufficient width to embrace the side of the seat.

The instrument panel was very simple. It was notable for having two tachometers driven separately from the back end of each camshaft. This seems to argue at once a degree of pessimism as regards the reliability of the instrument, and of alarm lest the prescribed revolution limit should be exceeded. Under the scuttle was a reserve tank and the scuttle itself was quickly detachable, thereby facilitating removal of the gearbox.

The engine of the P3 was, as has been previously mentioned, a direct development of the Monza type. The train of gears placed between the two cylinders to drive the camshafts and blowers was the same, the valve gear, crankcase, crankshaft, were similar. The basic difference was a change of cylinder dimensions which brought the stroke/bore ratio from 1.29: 1 up to 1.54: 1. Constructionally a major change consisted in the transfer of the inlet system from the right to the left hand of the engine (exhaust vice versa), and the use of two small capacity blowers each feeding one cylinder block, whereas

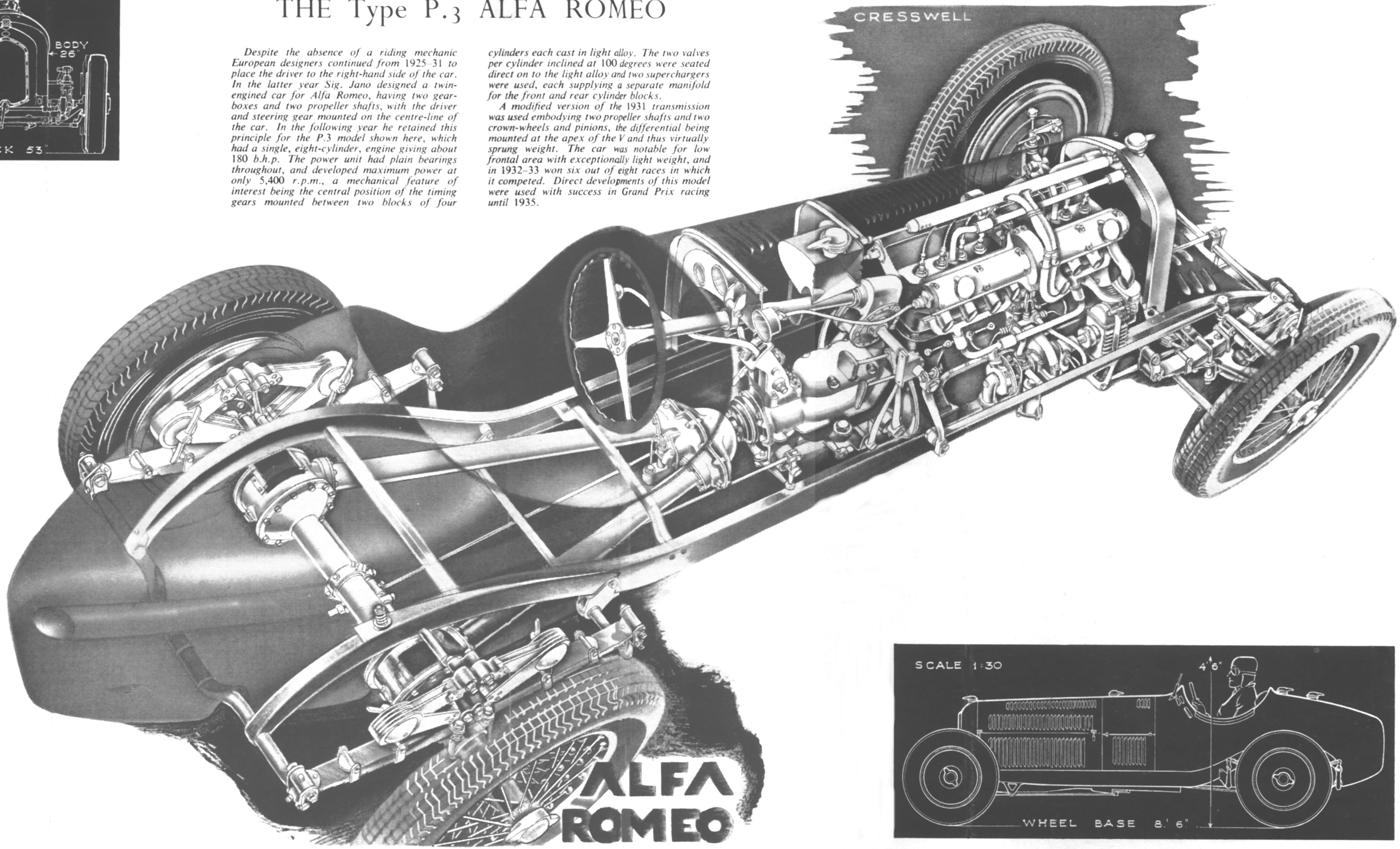
EXAMPLE No. THIRTEEN



THE Type P.3 ALFA ROMEO

Despite the absence of a riding mechanic European designers continued from 1925–31 to place the driver to the right-hand side of the car. In the latter year Sig. Jano designed a twin-engined car for Alfa Romeo, having two gear-boxes and two propeller shafts, with the driver and steering gear mounted on the centre-line of the car. In the following year he retained this principle for the P.3 model shown here, which had a single, eight-cylinder, engine giving about 180 b.h.p. The power unit had plain bearings throughout, and developed maximum power at only 5,400 r.p.m., a mechanical feature of interest being the central position of the timing gears mounted between two blocks of four cylinders each cast in light alloy. The two valves per cylinder inclined at 100 degrees were seated direct on to the light alloy and two superchargers were used, each supplying a separate manifold for the front and rear cylinder blocks.

A modified version of the 1931 transmission was used embodying two propeller shafts and two crown-wheels and pinions, the differential being mounted at the apex of the V and thus virtually sprung weight. The car was notable for low frontal area with exceptionally light weight, and in 1932–33 won six out of eight races in which it competed. Direct developments of this model were used with success in Grand Prix racing until 1935.



the Monza type had one blower feeding all eight cylinders. It may be estimated that the P3 engine developed approximately 190 b.h.p. at 5,400 r.p.m., this being the equivalent of 173 lb. per sq. in. at 3,550 f.p.m. piston speed, a useful but by no means outstanding figure.

The general construction of the engine is so clearly shown in the accompanying drawing that few words are needed to outline the main constructional details. The top and bottom halves of the crankcase and the cylinder block and the valve covers were all made in light alloy, steel liners being fitted into the bores. The valves (as shown) seat directly in the integral light-alloy head. The connecting rods were steel and the pistons, of conventional racing design with dome crown, gave a compression ratio of *circa* 6.0 : 1.

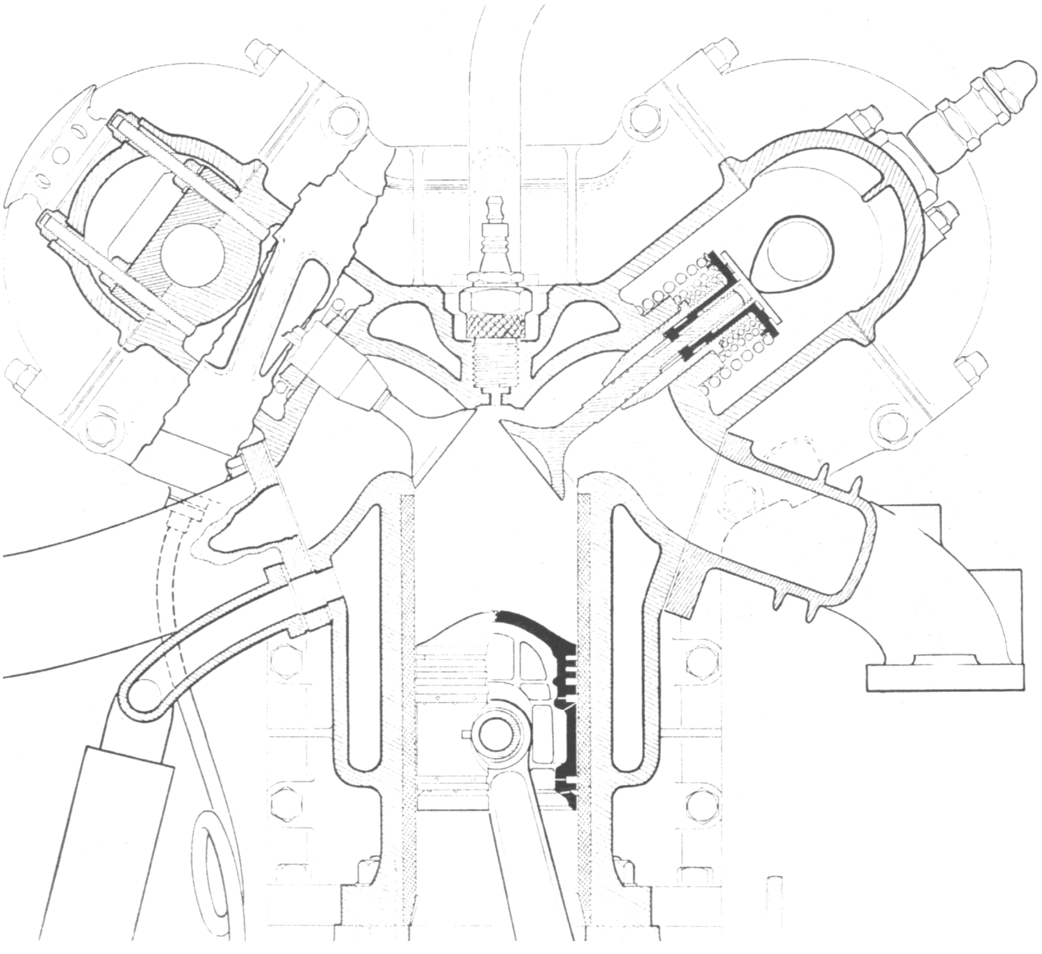
The valves followed the common European practice of 100 degrees included angle, and the cams operated direct on to the valve stems. The side thrust from the cam was taken first on to a steel mushroom which was screwed on to the end of the valve, and this transferred the load to another mushroom which was pushed over the valve and prevented from rotating by an engagement with two slots. The faces between the two mushrooms were serrated, and clearance can be obtained by screwing down the top member. Normally the two were held locked together by the pressure of the triple valve springs. The lower mushroom slides in an enlarged portion of the valve guide.

The head and valves were symmetrical, so that either port could be used for inlet or exhaust, according to the mounting of the block on the crankcase. There was good water flow around the valve seats and partly owing to the absence of any insert large diameter valves (39 mm.) were fitted. Heat transfer from the exhaust valve through the guide was, however, limited by the comparatively small area of steam in contact with the guide, and the equally limited cooling of the guide itself.

The valve opening was identical for both the inlet and exhaust sides of the engine, the inlet opening 20° before top centre and the exhaust closing 20° after top centre ; the exhaust opening 50° before bottom centre and the inlet closing 50° after bottom centre. Both valves had the same lift of 9 mm.

As will be seen in the accompanying drawing, the central gear on the crank engaged with an intermediary, which in turn coupled with a gear (having internal.and external teeth) which took the drive direct to the rotors of the two blowers. The number of external teeth on this gear could be changed and provision made for correspondingly changing centres of the driving and driven wheels. Having rotors 90 mm. long, each blower had a theoretical swept volume of 1,350 c.c., and, assuming 80 per cent volumetric efficiency, they were jointly capable of providing a 72 per cent boost running at 1.1 times engine speed, which is equivalent to just under 11 lb. gauge pressure.

Each blower delivered to one block of four cylinders, despite the fact that the crankshaft is the conventional straight-eight arrangement with the equivalent of one four-cylinder engine in the middle with the front and back half of a four on each side of it. The ideal porting of such an engine would be, therefore, one inlet tract to the centre pair of cylinders, Nos. 4 and 5, one to Nos. 3 and 6, one to Nos. 2 and 7, and yet another to Nos. 1 and 8. That is to say, the cylinders would be so paired that



Cross section of the P3 engine. Scale 1 : 3

one would be in the front block of four, another in the back block. Such an arrangement would be complicated, but the chosen layout, although it satisfied the Latin passion for superficial logic and neatness of form, carried these qualities to a point where they became a perversion, for it satisfied the demands neither of distribution nor even feeding impulses.

The crankshaft was made in two pieces bolted together in the centre through the main timing wheel and running in ten plain bearings. It was fully counter-weighted, lubrication being by pressure from a gear-type oil pump mounted on the offside of the engine. The rods were machined all over and, although somewhat primitive in section, had stiffening ribs. The length of the rod was 2.15 times the stroke ; the gudgeon-pin diameter was 18 mm.

Each camshaft ran in three long, plain bearings, and the near-side shaft drove a small air pump to provide fuel pressure. Large-size breathers were provided on the camshaft cover, the crankcase breathing through large-bore copper pipes, bent round to finish close to the gauze over the intake for the Weber carburetters. The single magneto, disposed on the right-hand side of the engine, gave current for the 18 mm. Champion plugs (Type R. 11), and the latter were well cooled but heavily masked. For these reasons plug bother, either burning or oil, was absent from these engines, which, apart from cracked valve seats, were thoroughly reliable.

This is to be expected in view of the comparatively low specific output, and one cannot help feeling that no really serious effort was made to increase the power per litre. The maximum speed was probably as great as was desirable on a car of such low weight with fixed axles, and the low-speed torque was, in any case, more than the gearbox could reliably absorb. As is well known, stripped gear teeth was a serious trouble on the P3, particularly as the swept volume, and thus the low-end torque, was steadily increased from the original 2.65 litres by successive enlargements of the cylinder bore. In its later forms the designer endeavoured to overcome this trouble by taking out the first speed and widening the gear teeth, but this modification does not, strictly speaking, come within the framework of this chapter as it was not undertaken until 1935.

Acknowledgments.-Thanks are due to Messrs. A. F. Ashby, R. Arbuthnot, T. D. Crook, Kenneth Evans and Thomson and Taylor, Ltd., in obtaining the foregoing data upon this car.

ALFA ROMEO P3-RACING RECORD

Date	*Evenr*	*Course*	*Average Speed*	*Lap Speed*
5/6/32	Italian G.P. . . .	Monza	104.13 m.p.h.	112.7 m.p.h.
3/7/32	French G.P.	Rheims	92.26 m.p.h.	99.5 m.p.h.
17/7/32	German G.P. . . .	Niirburg	74.13 m.p.h.	77.55 m.p.h.
1l/9/32	Monza G.P. . .	Monza	110.8 m.p.h.	113.7 m.p.h.
13/8/33	Coppa Acerb0 . . .	Pescara	88.03 m.p.h.	—
10/9/33	Italian G.P. . .	Monza	108.58 m.p.h.	115.8 m.p.h.
24/9/33	Spanish G.P.	San Sebastian	83.32 m.p.h.	—

DETAILS OF CAR

MAKE.-Alfa Romeo
TYPE.-P3
YEAR OF CONSTRUCTION.-1932
YEARS RACED.-1932-33 and (Type B) 1934
DESIGNER.-Jano
WHEELBASE.--8ft. 6in.
TRACK FRONT.-4ft. 5in.
TRACK REAR.-4ft. 5in.
HEIGHT TO SCUTTLE.-42½ in.
HEIGHT TO DRIVER'S HEAD.-54in.
MAXIMUM WIDTH.-26in.
FRONTAL AREA.-10.25 sq. ft.
UNLADEN WEIGHT.-15.2 Cwt.
ALL-UP STARTING LINE WEIGHT.- 18.2cwt.
MAXIMUM SPEED.-140 m.p.h.
SPEED ON INDIRECT GEARS.-102 m.p.h. on 3rd
,, ,, ,, ,, 70 m.p.h. on 2nd
,, ,, ,, ,, 40 m.p.h. on 1st
H.P./SQ. FT.-18.6
H.P./TON UNLADEN.-260
H.P./TON ALL-UP.-210
BORE.-65
STROKE.-100
S./B. RATIO.-1.54:1
NUMBER OF CYLINDERS.-8
CAPACITY.-2,650 c.c.
PISTON AREA.-41 sq. in.
B.H.P.-190
R.P.M.-5,400
B.M.E.P.-173 lb. sq. in.
PISTON SPEED FT./MIN.-3,550
CYLINDER HEAD.-Integral, Al
VALVES NO.-2
VALVES ANGLE.-100 degrees
VALVES AREA INLET.-14.8
VALVES AREA EXHAUST.-14.8
CYLINDER BLOCK.-A1 with dry steel liners

FUEL.-Petrol, Benzole or Alcohol
CARBURETTER.-2 Weber
SUPERCHARGER(S).-2 Roots
SUPERCHARGE PRESSURE.-1.6 ata. (101b. boost)
IGNITION.-1 Marelli Magneto
PLUGS NO.-8
PLUGS LOCATION.-Central in head
CRANKCASE.-Two piece, light-alloy split on c/line of bearings
CRANKSHAFT.-Two-piece counterbalanced, 2, 4, 2 layout
MAIN BEARING NO.-10
MAIN BEARING TYPE.-White metal
BIG END TYPE.-White metal
LUBRICATION.-Dry sump
CAMSHAFT NO.-2
CAMSHAFT LOCATION.-Jn head
CAMSHAFT DRIVE.-Train of gears
CAMSHAFT DRIVE LOCATION.-Centre of crank
CLUTCH.-Twin Plate
GEARBOX LOCATION.-Unit with engine
GEAR RATIOS.- 3.52 (3.3 optional)
,, ,, 4.56
,, ,, 6.54
11.8
TRANSMISSION.-Torque tube drive, divided propeller shafts to double bevels
FRAME.-Channel
FRONT SUSPENSION.-Semi-Elliptic
REAR SUSPENSION.-Semi-Elliptic
SHOCK ABSORBER TYPE.-Friction
BRAKE SYSTEM.-Mechanical
BRAKE DRUM DIAMETER.-15¾ in.
BRAKE DRUM WIDTH.- 1¾ in.
SQ. IN. PER TON LADEN.-380
WHEELS TYPE.-Rudge
TYRES.-28 x 5.50, front and rear

EXAMPLE No. FOURTEEN

Mercedes-Benz, Type W.25B

IN October 1932, that is to say after the first season of the P3 Monoposto Alfa Romeo, the A.I.A.C.R. introduced a new formula to cover Grand Prix motor racing for the three years 1934-36. The intention, which was to be dramatically falsified, was to lower what was then considered to be the dangerously high level of speed reached on the contemporary Maserati and Alfa Romeo cars which, with approximately 3-litre engines, could reach nearly 140 m.p.h. The means to this end were a weight limit, excluding driver, fuel, oil and tyres, of 750 Kg. (14.75 cwt.) and a minimum frontal area governed by a body width of at least 33½ in.

This ruling coincided with the rise to power of the Nazi Party. Already in Italy the Fascists had consciously used motor racing as an instrument of national prestige and international propaganda, and Hitler, who had a life-long passion for motor racing, and knew the winners of all the important racing events for many years, decided to encourage German constructors to follow this example.

A subsidy of £20,000 per annum was offered to both Mercedes-Benz and Auto-Union in 1934, but it may be doubted if this in itself counted for much when the subject of designing a pure racing car came up for discussion by the board of the Daimler-Benz Co., in 1932. Eight years had elapsed since either component of this amalgamation had embarked on a similar project, but a decision to compete under the 750 Kg. international formula was taken in March, 1933, and by May a team was got together under the leadership of Dr. Hans Nibel, who had originally been with the Benz Co. Assisting him was another member of the Benz Co., Wagner, who had been responsible for the rear-engined Benz racing cars of 1924. The question of making the new cars with rear engines was very carefully considered, but was rejected in the belief that :

(1) Rear engine mounting does not result in any weight reduction.

(2) As shown in wind-tunnel tests, the drag factor is about the same on both types.

(3) If the engine position and transmission are well arranged, the propeller shaft, running between engine and rear axle, presents no design problems.

(4) The smaller moment of inertia which is obtained with rear-engined cars has a beneficial effect in relation to the vertical axis, but is inconvenient in relation to the longitudinal axis and the suspension of the car, and adhesion to the road is impaired.

(5) It is particularly important on fast cars to have first-class adhesion for the front wheels, and on rear-engined cars the weight distribution is unfavourable in this respect.

Having decided upon the normal engine position on the foregoing grounds, work proceeded rapidly, and a complete car was sufficiently far advanced to be shown to Hitler in January, 1934, and was ready for road tests at Monza in March, 1934, ten months having elapsed for the whole of the design and construction period.

As a racing car, it was an interesting blend of the orthodox and the heterodox. The use of a straight-eight engine with a twin overhead camshaft and supercharging was in line with normal practice. Independent front springing, independent rear springing with combined gearbox and bevel box, a supercharging system feeding air under pressure to the carburetter, and hydraulic brakes were all distinctive breakaways from convention. Nevertheless, the whole car was obviously impregnated with traditional Unterturkheim thinking, despite the inclusion of two Benz men amongst the designers. This was most strongly shown in the design of the power unit and before analysing the details of the construction one must refer to the fundamental (and then somewhat surprising) decision of the responsible engineers that it would be possible to use four litres of swept volume without over-stepping the weight limit of 750 Kg., and that 400 b.h.p. on the flywheel could be usefully employed by the road wheels.

The last racing car built at Stuttgart was the eight-cylinder, 2-litre, model designed by Dr. Porsche and run by the works between 1924 and 1926. 160 b.h.p. was claimed for this model and road racing experience in the subsequent six years all went to show that this was about the maximum power which could be profitably utilised on ordinary road circuits. Alfa Romeo, Bugatti and Maserati had all it is true built larger and more powerful cars in the period 1929-33, but the successes of these models had been limited to exceptional circuits such as Monza and A.V.U.S. The decision to override the example of experience was undoubtedly based on the belief that the problem of transmitting vastly more power into the rear wheels could be solved by using independent suspension for each wheel and by thus eliminating the torque reaction effect which lifts the entire axle around the bevel pinions on the car with orthodox axles and thus provokes wheel spin.

The use of independent suspension for the front wheels would, it was thought also permit the use of increased maximum power by enabling the driver to control the car at far higher speeds than had hitherto been reached on the road.

Experimental work on independently sprung cars had been going on at Stuttgart for two or three years and some of the smaller models of the range had used independent suspension on all four wheels since 1932. On these cars a transverse leaf spring and wishbones was used at the front end, and a swing axle with coil springs at the back of the car. The choice of independent suspension all round for racing cars was thus not an adventure into the unknown, but from a technical viewpoint it is interesting to note that the type of spring was reversed as compared with the touring cars ; that is to say, leaf springs were used for the swing axle at the rear, coil springs for the front wheels.

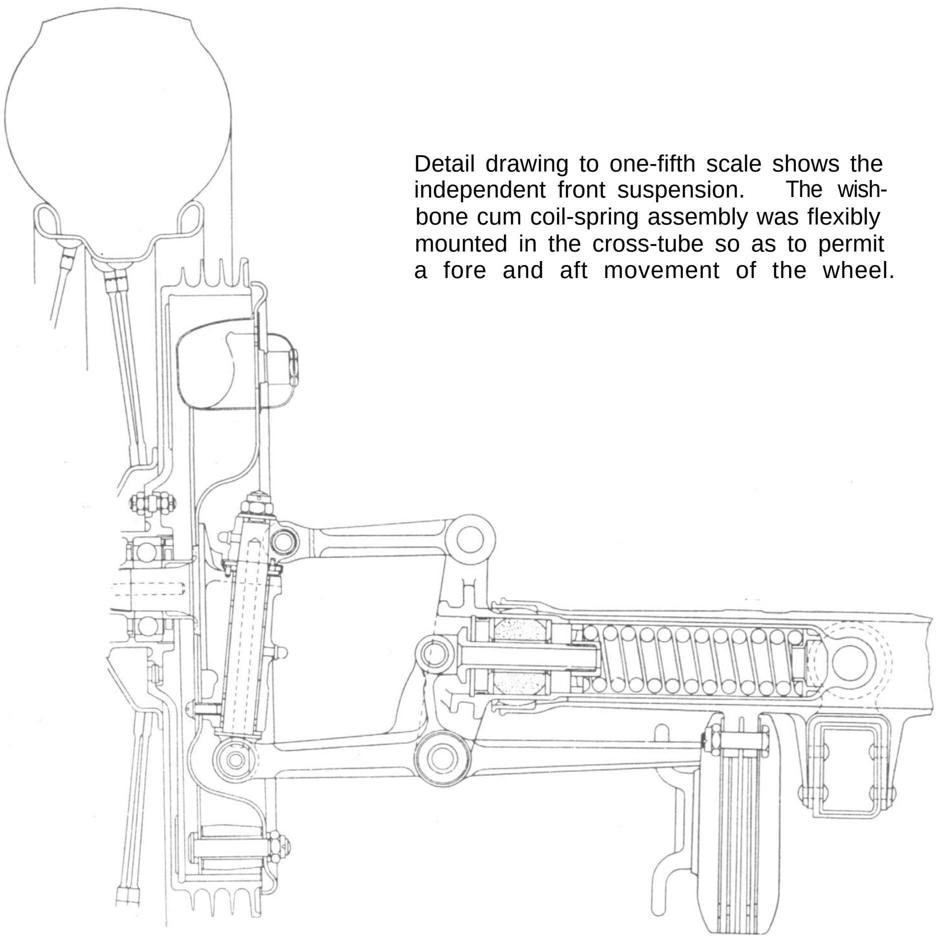
At the front end of the W.25 a cross-tube with an o.d. of 2¾ in. was superimposed upon the box section frame member, which was also 2¾ in. deep at this point, increasing to 6.4 in. by the scuttle. The suspension wishbones were pivoted on to this tube and were of equal length (5 in.), with their pivot points spaced 5½ in. apart.

From the time when they commenced development work on i.f.s. systems Mercedes-Benz engineers have sought to provide wheel movement in a horizontal as well as in a vertical plane. They took out a number of patents on methods to secure this end in conjunction with transverse leaf and other types of spring. On the W.25 racing car the entire wishbone assembly could pivot around a bearing mounted at the outer end of the frame cross-member, the movement being restrained by stops placed on each side of the coil spring housing, this being clearly shown in the assembly photograph on a Plate.

The king pin was recessed deeply into the brake drum so that the bearings were widely spaced and gave first-class support to the wheel under severe lateral loads caused by high-speed cornering. This arrangement, of course, gave vertical motion for the front wheels and put the front roll centre at ground level.

Coil-type springs were employed having a length, under normal load, of 5½ in., and o.d. of 1¾ in. These springs were placed inside the cross-tube and connected to the bottom wishbones through a bell crank ; the lever relationship between this and the wheel arm being 0.45 to 1.

This suspension system was coupled to a friction damper moved by a long extension of the bottom wishbone.



Detail drawing to one-fifth scale shows the independent front suspension. The wish-bone cum coil-spring assembly was flexibly mounted in the cross-tube so as to permit a fore and aft movement of the wheel.

The vertical travel from normal to full bump with this arrangement was limited to 1.8 in., and obviously, although these cars were provided with independent springing, they were far from offering the soft low-rate suspension which later proved highly beneficial. As a consequence, the slight error in geometry arising from the fact that the short swinging track rods differed in length from the suspension wishbones did not give rise to any serious consequences in the shape of severe reactions passed through to the steering wheel.

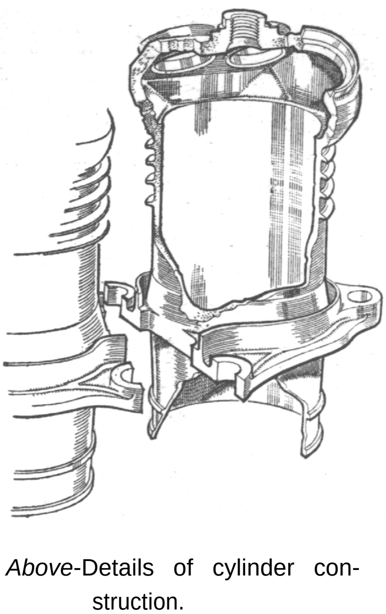
With the exception of Maserati all Grand Prix racing cars from 1923 to 1934 employed mechanical braking systems, but with the advent of independent suspension it became obvious that it would be difficult to arrange the required linkage. For this

reason, and for the added attraction of weight saving, the Mercedes-Benz used Lockheed on both front and rear wheels. The aluminium drums were notable for their unusual width of 2¾ in. and for the use of very stiff light alloy brake shoes expanded in the normal way by Lockheed assembly connected to a pair of master cylinders both joined to the pedal. By using a floating balance member it was possible to change the proportion of braking between front and rear by modifying the pivot point whilst damage to one of the pipe lines could not result in more than a pair of brakes being put out of operation. Additionally, on the W.25B a handbrake was mechanically connected to the rear shoes.

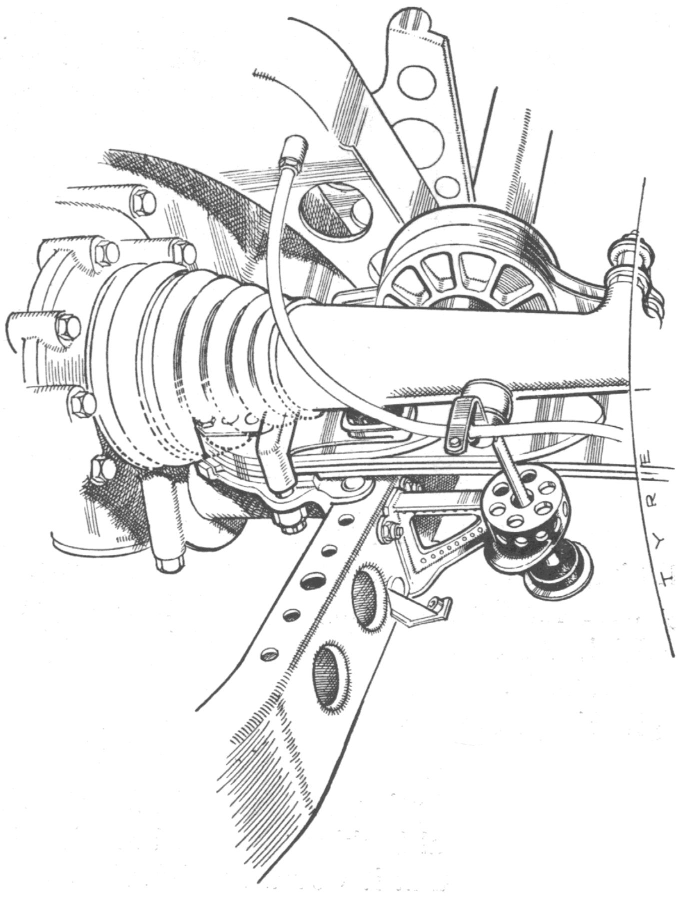
Steering was by the traditional Mercedes worm and nut, this arrangement giving 2¼ turns from lock to lock on a 41 ft. turning circle.

The box-section frame was liberally pierced at the front end to reduce weight and reinforced by two cross-tubes of 2 in. diameter riveted to brackets, and at the rear end the combined bevel box and gearbox casting was mounted on a 3 in. diameter cross-tube.

The four-speed gearbox was of normal design, except that all ratios were indirect, the propeller shaft thereby being lowered by 3½ in. with the crankshaft on the same line. Trunnion bearings on each side of the bevel box located tubes connecting to the rear hubs and enclosing the driving half-shafts. In this design a single universal was placed each side of the bevel box and the term " swing axle " used to denote the fact that each wheel swings around an arc struck from the axis of the trunnion.



Above-Details of cylinder construction.



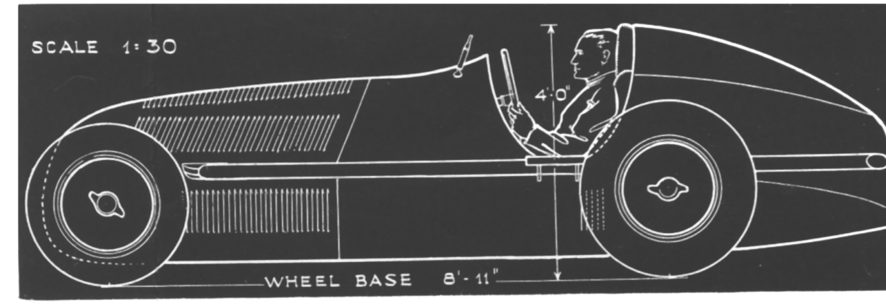
Right- The independent rear suspension utilised quarter-elliptic springs only 14½ inches long.

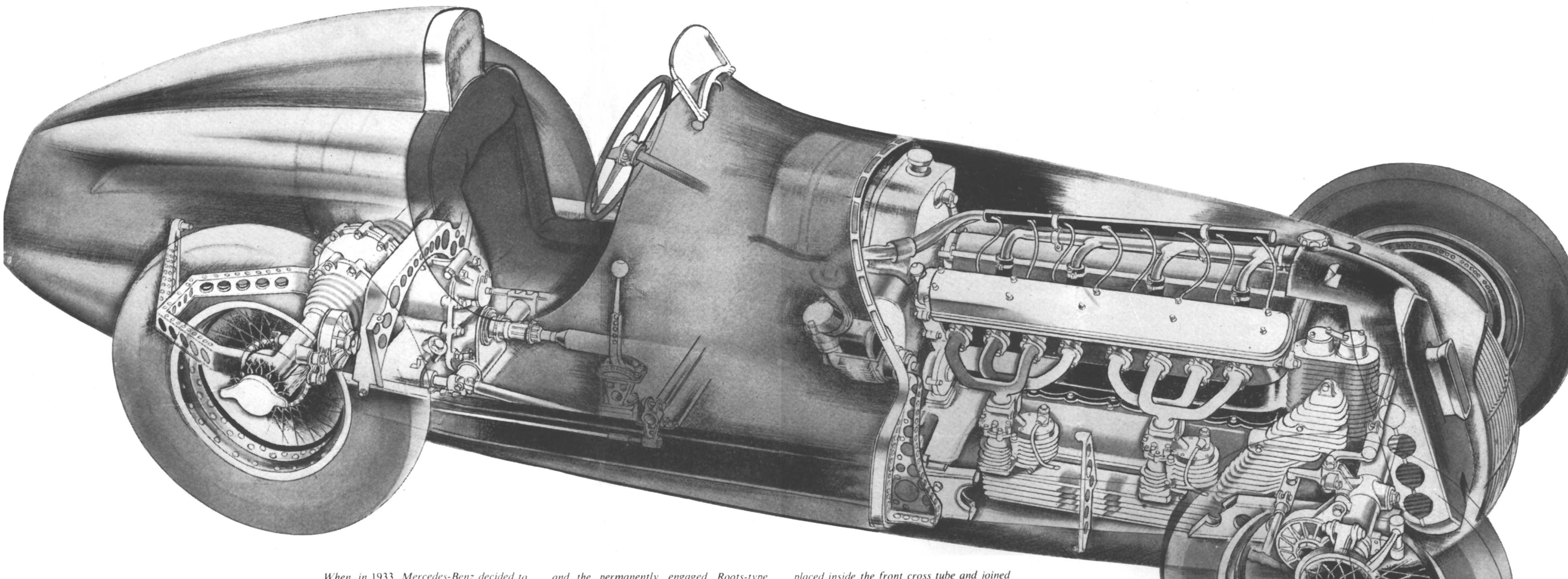
PLATE XXVI

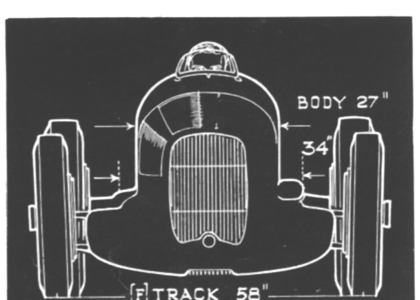
EXAMPLE No. FOURTEEN

THE 1935 MERCEDES-BENZ

Type W.25B







When, in 1933, Mercedes-Benz decided to return to Grand Prix racing after an absence of nine years they built a highly original design under the direction of Dr. Ing. e. h. Hans Nibel. Despite the drastic weight limit of 750 Kg. maximum for the years 1934–37 they used an eight-cylinder 3.36-litre engine giving 300 b.h.p. on Benzol mixture. The capacity and output were quickly raised to 3.99 litres and 430 b.h.p. on alcohol mixture.

Designed by a Benz-trained man the car was nevertheless redolent of Mercedes practice. The forged-steel cylinders were assembled in blocks of four with welded-on jackets, and the permanently engaged Roots-type blower, running at 2.78 times engine speed, delivered pressure air to the two double-choke carburetters. Also in the line of tradition was the use of four valves per cylinder, inclined at 60 degrees and roller bearings for both main and big-ends, the latter being split to permit the use of a one-piece crankshaft which ran in five bearings in the barrel-type crankcase. The gearbox was built in one unit with the bevel box and both were fixed to the frame, the drive being taken through swinging half-axles with a short transverse leaf spring beneath them. The front wheels were also independently sprung, coil springs being placed inside the front cross tube and joined to the suspension links by bell cranks.

The frame was made from pierced box section. The driver was centrally mounted, the seat height being reduced by the use of indirect gears which lowered the propeller shaft in relation to the rear axle centre line. The radiator was enclosed by a curved cowl, but the traditional wedge-shaped tail was continued.

This car, capable of some 175 m.p.h., won two out of the five major races for which it was entered in 1934 and five out of seven in 1935.

Suspension was by a quarter-elliptic spring on each side of the car, each one of which had four leaves 3-1/8 in. wide with only 14½ in. in length between the clamp point and the outer shackle.

The total deflection permitted by rubber stops was 2.4 in., the movement from the normal position to full bump being only 1.2 in.

It is apparent that at the rear, also, the suspension was of the solid type compared to later developments, although probably more flexible than that provided on contemporary cars. It must, however, be emphasized that the benefits of independent springing on these early cars were not derived from very large vertical motion on the wheels.

Looking at the overall design one finds that the swing axle system gave a roll centre 2-3/8 in. above the universals at the back, and that the rear springs were much stiffer than the front. In consequence one would expect these cars to have a marked oversteering tendency and there is, in fact, good ground for believing that they were markedly slower on corners than the more conventionally sprung vehicles. On the other hand, the absence of transverse torque effect on the rear wheels gave them a big advantage when accelerating away from corners, and also promoted steadiness on the straight at high speeds. The former aspect was particularly noticed by the drivers of competing cars, who found that when they were struggling with wheel spin the German cars were using their immensely superior h.p. per ton to full advantage.

The engine originally installed for the 1934 season was an eight-cylinder 78 x 88 mm. giving a swept volume of 3.36 litres. This gave 354 b.h.p. on alcohol fuel, but before the end of the year it had been replaced by the M.25AB power unit in which the bore had been enlarged to give dimensions 82 x 88 mm. (swept volume 3.71 litres), and the M.25B 82 x 94.5 mm. with a swept volume of 3.99 litres. The last named gave 430 b.h.p. and weighed 468 lb. compared with 453 lb. for the original engine.

Apart from the small changes in bore and crank throw these engines were identical.

In accordance with Mercedes practice dating back to the 1914 G.P. winner, the cylinder blocks were fabricated from separate Krupp steel forgings. These were welded in sets of four to a base plate and had built-up and welded-in valve ports. Each block of four cylinders was surrounded by a water jacket 1.0 mm. thick, a construction that is exceedingly light and gives very close control over water spacing and passages. The cylinder head was asymmetrical and again, in accordance with Mercedes tradition, four valves per cylinder, each of 34 mm. diameter, were used. These valves were inclined in the cylinder head at an included angle of 60 degrees, the cylinder head being slightly thicker than the walls, the latter being 2½ mm. and the former 6½ mm. Supports for the valve guides were welded in situ and the camshaft boxes were separate castings in one piece bolted on to the top of the block and running the whole length of the engine. On the M.25 series the cylinder blocks were bolted to a light alloy barrel-type crankcase casting which was extended at the front end to include the mounting for the Roots type blower and the bevel drive thereto. This casting was 1,044 mm. long, 217 mm. deep, and 275 mm. wide (say 40 in., 8½ in., and 10¾ in.).

A ribbed, light-alloy sump was bolted on to the bottom of the case and the crankshaft complete with main bearings inserted into the crankcase proper from the rear end.

The crank was unusual in having five main bearings, the intermediates being placed between two and three, four and five, and six and seven. The crankshaft was

one piece and counterbalanced ran on roller main bearings with split races, the front bearing being 52 mm. diameter and the other four bearings 63 mm. diameter. The centre bearing had hardened tracks 25 mm. wide, the others running on tracks only 80 mm. wide. The centre of each track was relieved by an oil groove 3 mm. wide which connected with the pressure side of the lubrication system. There were no internal oil ways in the crank, oil from the main bearings being thrown off into recessed collector rings machined in the cheeks of the crankshaft and thence through the hollow crankpins through a 3 mm. hole into the big ends. The fillets between the cheeks for both main and crankpins were notable for exceptionally deep radii.

The crankpins were 53 mm. diameter, the tracks being 19.5 mm. wide, minus the area of an oil delivery recess. The crankshaft being in one piece, the big ends and the connecting rods were split, the caged rollers running directly in a hardened track formed inside the rod and cap. Serrations were provided at the joint between the two and on these rods four big-end bolts were used.

Conventional H-section rods with very carefully designed blending into the big end were employed, the gudgeon pins being splash-lubricated.

The pistons were of completely conventional design having a pronounced crown and made by Mahle in Y alloy.

Valve gear comprised two overhead camshafts lifting the 34 mm. diameter valves 8.5 mm. through the intermediary of fingers. Each camshaft was 32½ in. long, supported in five plain bearings and driven by a train of gears from the rear end of the engine. These gears were also extended below the crankshaft centre line to provide a drive for the gear type oil pumps, the scavenge pump delivering to a tank on the scuttle containing eleven gallons of pure castor oil. The fuel and water pumps were driven from a right angle drive at the opposite (forward) end of the engine. Fuel was supplied to the pressure type carburetters by an aircraft type pump with a spring loaded by-pass valve, the suction side being connected to the tank which was formed in one piece as the tail of the body.

The fuel pump was placed on the offside of the engine, the water pump on the nearside, the latter delivering water to the exhaust side of the cylinders with four 1.2 in. diameter offtake pipes mounted above the cylinder heads.

Ignition was by 18 mm. Bosch sparking plugs threaded directly into the cylinder head and only slightly masked. The Bosch magneto was driven from the back of the timing gears and projected into the driving compartment.

The supercharger was placed at the extreme nose of the engine and the rotors mounted vertically and driven continuously by bevel gears at twice engine speed.

In accordance with Mercedes tradition dating back to 1922 pure air was fed to pressurised carburetters mounted in the orthodox position in relation to the inlet manifold. Whereas, however, the volume of air delivered had on the earlier cars been controlled by a friction clutch which engaged the blower only on full throttle, on the 1934 design the same effect was contrived more simply and with lower weight by a relief valve inter-connected with the carburetter throttles.

The need for such a device will become apparent if it is appreciated that a blower running at a fixed speed in relation to the engine, and with no throttle on the intake side builds up an excessive pressure in the pipe leading to the carburetters when the throttles in the latter are partly or wholly closed. To avoid the very high temperatures which

would result from this phenomenon a butterfly throttle was mounted on the delivery side through which excess air could be vented into the atmosphere. As the carburetter throttles reached a position in which the engine required pressure air the spill valve was shut off being until, of course, it was closed with the throttle fully opened. This device led to the extremely high pitched supercharger scream which was characteristic of the early Mercedes-Benz engines.

All the M.25 series engines had supercharger rotors measuring 106 mm. from tip to tip, the length varying with the particular mark and capacity of the engine. On the B type the length was 240 mm. and theoretical delivery 1.72 litres per revolution so that, taking the blower gear ratio of 2: 1 into account, there was a total theoretical delivery of 3.44 litres per revolution of the crankshaft. This gave a boost of 1.66 ata, or say 10 lb. gauge pressure, a figure somewhat magnified by the high output air temperature.

The pressure air was delivered from the blower through a deeply ribbed light alloy manifold to a pair of twin choke carburetters, each feeding one set of cylinders so that each jet and choke assembly fed only two cylinders, the grouping being one and three, two and four, five and seven, six and eight. These groupings correspond with the firing order and result in two consecutive deliveries followed by a long interval. On the other hand, the pipe lengths are nearly the same. It will be recognised that the float chamber as well as the choke tube was subject to boost pressure and the fuel pump had to deliver into the sealed float chamber against this contra pressure.

With this system the latent heat of the fuel played little part in lowering the manifold temperature, and the resultant high supercharge temperatures led in turn to wide clearances so as to avoid seizure. These resulted in a marked drop in the m.e.p. curve below 3,000 r.p.m., the peak of the torque curve being reached at 4,000 r.p.m. Power was delivered by a plate clutch to the fixed gear-cum-bevel box aggregate at the rear of the car through a propeller shaft 2¼ in. diameter, the engine being mounted squarely in the frame on both axes.

During the three years 1934-36 five marks of this five-bearing type of engine were produced. In detail they were :

Mark	*Dimensions*	*Capacity Litres*	*Weight*	*B.H.P.*
M.25A	78 x 88	3.36	449 lb.	302 (354)
M.25AB . .	82 x 88	3.71	449 lb.	348 (398)
M.25B .	82 x 94.5	3.99	456 lb.	430
M.25C . .	82 x 102	4.3	473 lb.	415 (462)
ME.25 . .	86 x 102	4.74	465 lb.	456 (494)

Two sets of power figures are given in the above table, the first being for the engines as tested in the early stages of development over the full range from 1,500 r.p.m. up to a maximum of 5,800 r.p.m. (in some cases running on petrol : benzole) and italicised figures in parenthesis which give the highest power recorded at maximum r.p.m. at any stage during the life history of a particular unit. In every case the higher figures were achieved using W.W. fuel (*vide* example No. 16).

These figures and the curves reproduced in Chapter 30 show that although there was a steady gain in power output there was a regression of m.e.p. at a given

piston speed. This was only to be expected as the engines became progressively short of valve area in relation to swept volume. The Mercedes-Benz W.25 series were exceedingly successful in their racing programme, particularly during the first two years. In 1934 results measured either by race wins or average speeds were not decisive and the cars won only four out of ten major races held. Dr. Nibel died in November, 1934, and thus did not live to see the major successes achieved in 1935 in which his designs won eight out of ten major races.

Acknowledgments.-Full assistance was given by the constructors and in particular Directors Wagner and Hoppe, and racing mechanic Müller.

DETAILS OF CAR

MAKE.-Mercedes-Benz
TYPE.-W.25B
YEAR OF CONSTRUCTION.-1935
YEARS RACED.-1934 Engines M.25A
1935 Engines M.25B and M.25C
DESIGNERS.-Nibel and Wagner
WHEELBASE.-8 ft. 11 in.
TRACK FRONT.-4 ft. 10 in.
TRACK REAR.-4 ft. 7 in.
HEIGHT TO SCUTTLE.42 in.
HEIGHT TO DRIVER'S HEAD.-48 in.
FRONTAL AREA.-11.8 sq. ft.
UNLADEN WEIGHT.-16.8 cwt.
ALL-UP STARTING LINE WEIGHT.-20 Cwt.
MAXIMUM SPEED.-175 m.p.h.
SPEED ON INDIRECT GEARS.-According to circuit
H.P. PER SQ. FT.-36.5
H.P. PER TON UNLADEN.-510
H.P. PER TON ALL-UP.-430
BORE.-82 mm.
STROKE.-94.5 mm.
S./B. RATIO.-1.15:l
No. OF CYLINDERS.-Eight
CAPACITY.-3,990 c.c.
PISTON AREA.-65 sq. in.
B.H.P.-430 at 5,800 r.p.m.
H.P. SQ. IN.-6.62
B.M.E.P.-242 lb. per sq. in.
PISTON SPEED FT./MIN.-3,600
CYLINDER HEAD.-Integral with steel cylinders
VALVES No.-Four per cylinder
VALVES ANGLE.-60 degrees
VALVES AREA INLET.-22½ sq. in.
VALVE AREA EXHAUST.-22½ sq. in.
CYLINDER BLOCK.-Forged-steel barrels welded together in sets of four with sheet water-jackets
FUEL.-Petrol-Benzole or alcohol mixture
CARBURETTERS.-Two double choke Mercedes-Benz
SUPERCHARGER.--One Roots at 2.0 engine speed
SUPERCHARGE PRESSURE.-10 lb. boost (1.66 ata.)
IGNITION.-one Bosch magneto
PLUGS No.-Eight
PLUGS LOCATION.-Centre in head
CRANKCASE.-Barrel type with crank inserted from end
CRANKSHAFT.-One-piece counterbalanced
MAIN BEARING No.-Five
MAIN BEARING TYPE.-Roller
BIG END TYPE.-Roller in split housing
LUBRICATION.-Dry Sump
CAMSHAFT No.-Two
CAMSHAFT LOCATION.-In head
CAMSHAFT DRIVE.-Train of gears
CAMSHAFT DRIVE LOCATION.-Rear of crank
CLUTCH.-Single plate
GEARBOX LOCATION.-In unit with bevel box
GEAR RATIOS.--According to the circuit
TRANSMISSION.-Open propeller shaft 3½ in. below centre line of hubs. To step up gears on combined gearbox and bevel drive. Swing axle with enclosed half-shafts to rear wheels
FRAME.-Pierced box section
FRONT SUSPENSION.-Independent to each wheel with bell crank connecting to horizontal coils placed within front cross-member
REAR SUSPENSION.-Independent to each wheel with swing axle. Transverse mounted quarter-elliptic leaf springs
SHOCK ABSORBER TYPE.-Friction
BRAKE SYSTEM.-Lockheed hydraulic
BRAKE DRUM DIAMETER.-15¾ in. internal
BRAKE DRUM WIDTH.-2 in. front, 2¾ in. rear
SQ. IN. PER TON LADEN.-272
STEERING.-Worm and nut 2¼ turns lock to lock
WHEELS TYPE.-Rudge
TYRES.-Front 525 by 17
Rear 525 by 19

RACING RECORD MERCEDES-BENZ, TYPE W.25

Date	*Event*	*Course*	*Average Speed*	*Lap Speed*
3/6/34	Eifel Races	Nürburg Ring	76.12 m.p.h.	79.00 m.p.h.
1/7/34	French G.P	Montlhery	N.F.	89.5 m.p.h.
15/8/34	Coppa Acerbo	Pescara	80.26 m.p.h.	—
9/9/34	Italian G.P	2.68 Miles at Monza	65.37 m.p.h.	—
23/9/34	Spanish G.P	San Sebastian	97.13 m.p.h.	100.8 m.p.h.
30/9/34	Czechoslovak G.P	Brno	—	82.29 m.p.h.
22/4/35	Monaco Grand Prix	Monaco	59.43 m.p.h.	60.08 m.p.h.
16/6/35	Eifel Races	Nürburg	72.98 m.p.h.	—
23/6/35	French Grand Prix	Montlhery with Chicanes	77.14 m.p.h.	—
30/6/35	Penya Rhin Grand Prix	Mountjuich	66.99 m.p.h.	68.94 m.p.h.
14/7/35	Belgian Grand Prix	Spa	97.87 m.p.h.	103.7 m.p.h.
28/7/35	German Grand Prix	Nürburg	74.5 m.p.h. (3rd)	80.73 m.p.h.
25/8/35	Swiss Grand Prix	Berne	89.95 m.p.h.	99.5 m.p.h.
22/9/35	Spanish Grand Prix	San Sebastian	101.92 m.p.h.	—

EXAMPLE No. FIFTEEN

The 6-litre Auto-Union Type C

WHEN, in 1933, the recently formed combine of four Saxon automobile companies, Horch, Audi, Wanderer, and D.K.W., called Auto-Union, decided to enter Grand Prix racing under the 750 Kg. formula, they were wise enough to take over a project which was already begun as a private venture by Dr. Ing. h. c. Ferdinand Porsche and his partner Adolf Rosenberger.

As is well-known, Dr. Porsche was in charge of design at Austro-Daimler from 1906-23, and in 1924 he had been responsible for the supercharged four-cylinder 2-litre Mercedes, and the extremely fast, if somewhat unstable, 2-litre eight-cylinder supercharged model. Herr Rosenberger was a wealthy amateur racing driver whom, it is not irrelevant to note, had many successes in 1925 with the 2-litre Benz rear-engined " tear-drop " cars. These ran in the Italian Grand Prix of 1923, and in the following year Rosenberger put up a record time for the Hercules hill climb, near Kassel, and was first, and made best lap, in the Solitude races. His Benz experience showed him that there were many virtues in a rear-engined racing car and, Porsche agreeing on technical grounds, the design for a 1934 G.P. model was based on a V. 16 cylinder engine placed behind the driver and ahead of the rear axle. The gearbox was driven by a sub-shaft and mounted behind the rear axle, and the fuel tank mounted between the back of the driving seat and the front of the cylinder block. A tubular frame was used to carry water from the engine to the front-mounted radiator, and all four wheels were independently sprung, using Porsche-type trailing links and torsion bars on the front and a swing axle with transverse leaf spring at the rear. As originally designed the A type P. Wagen had a bore and stroke of 68 x 75 mm. and the 4.36-litre engine developed 295 b.h.p. at 4,500 r.p.m. with a boost pressure of approximately 9 lb.

The car made its first public appearance on March 6, 1934 (when Hans Stuck broke three world records on the A.V.U.S. Track), and in the ensuing season of Grand Prix racing was successful in the German, Swiss and Czechoslovak Grands Prix, and took second place in the Italian Grand Prix. In 1935 the design was slightly modified (B type), torsion bars were used at the back and the bore was increased to 72.5 mm. Some 375 b.h.p. was now obtained at 4,700 r.p.m. from 4.95-litre capacity with a boost of 11 lb. per sq. in. The top speed of the car was, thereby, increased from approximately 170 to approximately 180 m.p.h., and running a prototype model at the end of 1934 Hans Stuck broke the standing kilometre record at 101.56 m.p.h. and the standing mile record at 116.75 m.p.h. (20/10/34, A.I., No. 254). These figures show that the car averaged 159.5 m.p.h. between the end of the kilometre and the mile post, but despite this excellent performance, Auto-Union won only one major race in 1935, the Italian Grand Prix, and three minor events, the Tunis and Czechoslovak Grands Prix and the Coppa Acerbo. In 1936, therefore, the car was subject to such a further and more substantial re-design and called the C type.

The main engine casting was unchanged but the swept volume was raised to over six litres, whilst a variety of modifications were made to the chassis. This model was used throughout 1936 and 1937, and in the former year was definitely the most successful car of the year in which it won three out of five major Grands Prix, and three out of six of the lesser events. The lap record was broken on six circuits during the year.

The improved performance of the C over the B type can be directly assessed by a study of the record book. The standing kilometre speed was raised to 117.3 m.p.h. and the standing mile to 134.5 m.p.h. (26/10/37, AI., No. 304), and the inferred average between two timing strips was 180 m.p.h.

With 520 b.h.p. available 205 m.p.h. was claimed as possible at 5,000 r.p.m., but there is no direct evidence that so high a speed was ever reached during road racing. A more accurate valuation can be based on a timed speed over five kilometres, which was 195.13 m.p.h. (23/3/36, A.I., No. 284), but even this was achieved with a combination of final gear ratio and tyre size used only for virtually track races, such as Tripoli and A.V.U.S. For the ordinary run of road racing ultimate speed was sacrificed for acceleration and the car was geared to 175 m.p.h. at 5,000 r.p.m. on top gear.

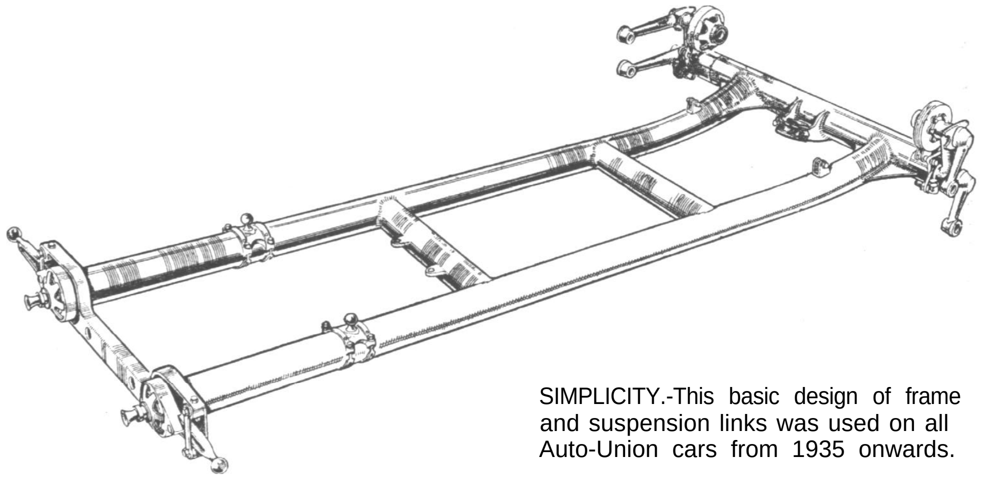
Although unorthodox in conception and execution the design of the Auto-Union was notable for simplicity and straightforward engineering with no effort to solve problems by resort to complicated expedients. The position of the fuel tank is a good illustration of the manner in which first principles were regarded. During the 750 Kg. formula, events were run over a fixed distance of 310 miles and as it was normally unnecessary to change a complete set of tyres at shorter intervals than 150 miles, it was clearly desirable for the car to run at least this distance without a fuel stop. Allowing, therefore, for a consumption at the rate of 3½ m.p.g., plus a reasonable margin, the tank had to hold a minimum of fifty gallons, amounting to 400 lb. in weight. On these figures there would be a difference of some 15 per cent between the weight of the car leaving the starting line and on its last lap before refuelling, and Dr. Porsche thought it highly important that this comparatively large variation should not result in any change in fore and aft weight distribution.

With a normal rear-mounted tank the proportion of weight carried on the rear wheels would fall from 58 per cent to 51 per cent, and the absolute loading from 12.2 cwt. to 9.2 cwt. Placing the tank on the mid-point of the chassis ensured that there was no change in the proportion, etc., weight distribution, the total variation in axle load being from 12.2 cwt. to 10.4 cwt.

As a direct consequence, however, of placing both fuel tank and engine behind the driver the latter was brought very far forward in relation to the wheelbase, the lower rim of the steering wheel being only 38 in. from the centre of the front hubs. On the other hand, it was possible to mount the driver very low on the car with no complication arising in respect of propeller shafts and clutch housings, etc. The top of the driving seat, therefore, was only 11 in. and the scuttle barely 35 in. from the ground. The general construction of the car also permitted an exceptionally low frame height.

The frame members themselves were round chrome molybdenum tubes 4.1 in. in diameter with a wall thickness of 0.10 in. (approximately 13 gauge), and as shown in a drawing the side tubes were parallel and slightly upswept at the front to join a tubular cross member, reinforcements being provided by wide radial fillets. This cross member was out-rigged to provide a mounting for the suspension units, two other tubular cross members being supplemented by a box section which tied together the extreme rear-end of the frame. Separate water pipes were used in 1936 as experience had quickly shown that the welds in the 1934 design were not 100 per cent watertight. This very simple structure weighed approximately 130 lb.

The front suspension units consisted of two trailing arms 3.75 in. long connected to the king-pin by ball and socket joints. Each bottom arm was joined to a 36 in. long torsion bar placed within the front cross member and extending the full width thereof, that is the anchor point for the bar at the offside wheel was on the nearside of the car and vice versa. The torsion bars were 16 mm. diameter and gave an overall deflection of 350 lb. per in., with a normal wheel movement above and below the neutral plane of 2.35 in.



SIMPLICITY.-This basic design of frame and suspension links was used on all Auto-Union cars from 1935 onwards.

The upper trailing link was mounted on a tubular stub welded to the main cross member and was connected to the rotating discs of an adjustable friction type damper.

This type of suspension resulted in the wheelbase shortening slightly on full bump, but in the straight ahead position gave immunity from gyroscopic reactions as the wheels had a complete vertical motion.

The worm and rocker shaft steering box was mounted on the centre line of the car, and the drop-arm was linked to individual track rods running to each wheel, but although this gave geometrically correct motion in the straight ahead position, errors in geometry arose when the wheels were turned on to the lock. The steering column was offset to the right at an angle of 2½ degrees and was surmounted by a 16½ in. diameter wheel which was quickly detachable so as to make it possible for the driver to enter and leave the car.

Suspension at the rear was also by torsion bars, a transverse link leading from the wheel and the bars being mounted inside the frame. At the back the torsion bars were 24 mm. diameter, but the suspension was considerably softer than at the front, being 233 lb. per in. It was easy to pre-load the bars through the medium of fine splines where they engaged the operating links. The latter were free from side loading or torque effects, as the rear axle assembly consisted of a swing axle with radius arms.

The driving shafts were contained in short axle tubes which ended in an hemisphere engaging with a similarly shaped bearing which took all side thrust and a single Porsche homokinetic joint lay upon the axis of this bearing on each side of the bevel box. Braking and drive torque were taken through short arms running at an angle of 57 degrees from the hubs to spherical joints on the frame, so that as the rear wheels rose and fell they were subject to changes in track and to variations of toe-in. Both

PLATE XXVII

EXAMPLE No. FIFTEEN

THE 1936 6-litre AUTO-UNION

The rear-engined cars, designed by Dr. Ing. h. c. Ferdinand Porsche for Auto-Union, competed in the 750 kg. formula of 1934–37 with great success.

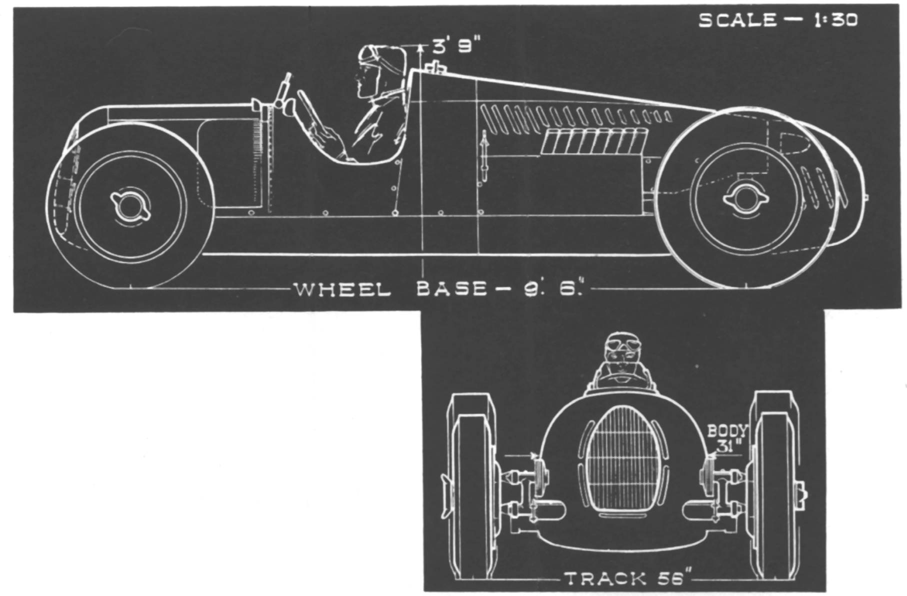
Although basically unchanged during the four years the engine capacity was raised in two stages from 4.36 litres to 6 litres, and engine output from 295 b.h.p. at 4,500 r.p.m. to 520 b.h.p. at 5,000 r.p.m.

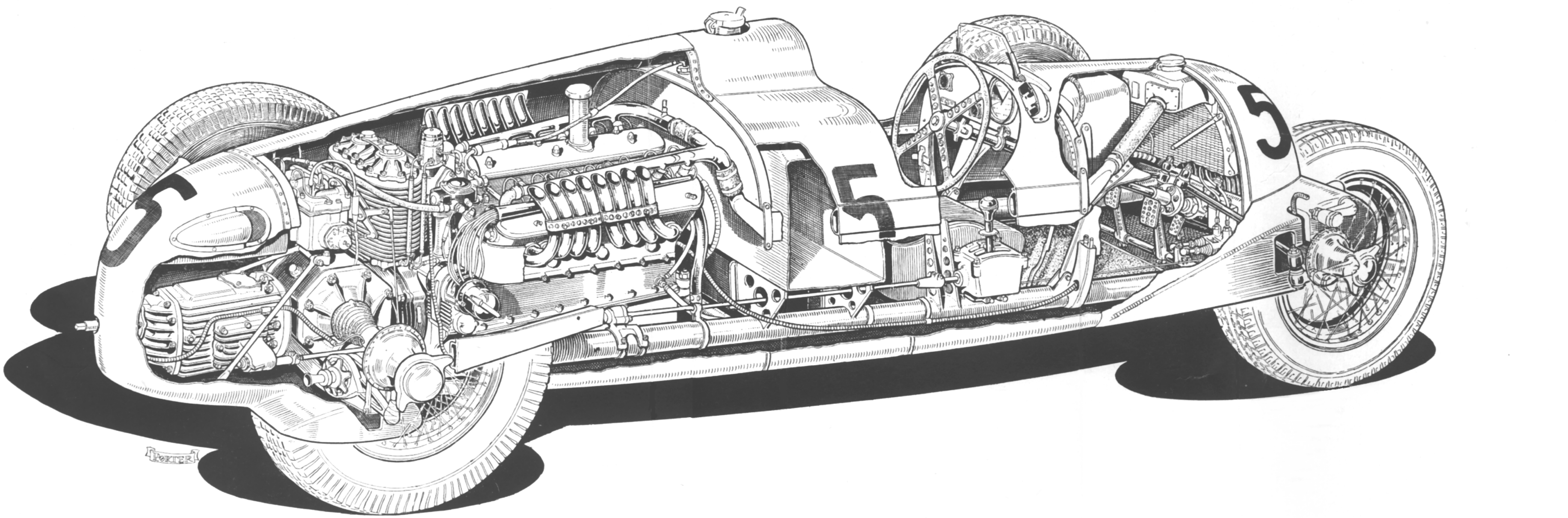
The sixteen-cylinder power unit was of basically simple construction, a light alloy casting forming both crankcase and water jackets with double cylinder liners. Two light alloy detachable cylinder heads with eight combustion chambers in each were extended to the centre line of the engine to form the inlet manifold and to provide a support for the single overhead camshaft which operated all thirty-two valves. The supercharger was driven by spur wheels from the vertical camshaft drive and the five-speed gearbox was mounted behind the rear-axle centre.

Drive to the rear wheels was through a Z.F. limited slip differential to swinging half shafts with torsion bar springs enclosed within the tubular frame. The front suspension was by trailing links with transverse torsion bars enclosed within the front cross member.

The forty-six-gallon fuel tank was placed between the engine and the driver and the latter, therefore, sat very far forward on the car. Weight distribution was, however, unaffected by changes in fuel level. These cars, with the highest possible gearing, would considerably exceed 200 m.p.h., and with the lower gearing used for road races would reach over 180 m.p.h. They were capable of averaging 117.245 m.p.h. over a kilometre from a standing start.

They won three out of five major races in 1936 and in the two seasons in which they were run by the manufacturers scored twelve victories in all.





front and rear suspensions were, however, of the utmost mechanical simplicity and the ratio of sprung : unsprung weight was 3.85 : 1.

The bevel housing was made from a steel casting and the gears which had a Klingelnberg-Palloid tooth-form offered alternative ratios of 3.0 or 3.3:1. A Z.F. limited slip differential was used, power being received from a five-speed gearbox. The ratios in this box were, of course, varied according to the circuit, further changes in the relation of engine to rear wheel speed being effected by changes of tyre size. Typical overall ratios in this box were 2.00 on first, 1.292 on second, 1.078 on third, 0.965 on fourth, and 0.863:1 on fifth. Thus, as between the highest and the lowest gear engine speed was increased by 2.32 times, but the high torque developed by the engine on the C Type made it possible for many races to be run using the two upper ratios only.

The gears were contained in a heavily ribbed casting of silicon light alloy, and the two shafts were arranged one above the other, the lower being connected to the clutch, the upper to the bevel pinion so that one pair of wheels was always engaged with no direct drive in the ordinary sense.

One selector fork moved a pair of ratios, i.e. second and third, and the fourth and fifth, these gears being coupled by dog clutches. The first and reverse gears, which were rarely used, were separately actuated. The gear-shaft bearings were positively lubricated by pressure oil supplied through a hollow clutch shaft and in addition the wheels themselves were sprayed by an oil stream when they were transmitting power. This was arranged by making the selector block open or mask the jet used for the appropriate gears.

As can be seen from the general arrangement drawing the box was placed behind the axle centre and a short shaft ran beneath the differential to connect with the twin plate clutch mounted at the back of the engine. The whole of the transmission unit was, of course, assembled as one piece with the power unit and lay at the slight angle of two degrees from the horizontal.

Reference has already been made to successive increases in engine size between 1934 and 1936, but although the cylinder diameter was increased in two stages from 68 mm. to 75 mm., and the stroke rose from 75 mm. to 85 mm., the cylinder centres remained unchanged. On the C Type engine, however, the crankshaft diameter was increased from 62 mm. to 70 mm. on the main bearings and from 58 mm. to 68 mm. on the big ends. As on the chassis, so on the engine, the general design, despite the use of sixteen cylinders, had a fundamental simplicity which compels admiration.

A single light-alloy casting of silicon alloy was extended below the centre line of the main bearings and upwards to embrace the water jackets of all sixteen cylinders. The bottom half of the engine was, in fact, simply an oil trap and contributed little to the stiffness, which was taken care of by webs which supported the main bearings which lay on each side of every crank throw.

The cylinder bores themselves were formed from wet steel liners, sealing at a face joint at the bottom and being located by the detachable cylinder-heads at the top. The latter were made in light alloy and contained two valves placed at 90 degrees, the inlet valve having a diameter of 35 mm. Both valves were seated on bronze inserts, the exhaust being on the outer side of the block and the inlet ports passing into the centre of the vee. A cross-section shows how the two heads were extended to form a

conduit running down the centre of the block, which received mixture from the rear-mounted Roots supercharger. One 18 mm. sparking plug was used per cylinder, offset slightly to provide for easy changing.

The narrow angle of the vee made it possible to work all thirty-two valves from one camshaft. This was driven by bevel gears from the back of the engine and ran along the centre line of the block. The cams worked the inlet valves directly through short followers, and the exhaust valves by push-rods running to the outside of the block and engaging with rockers. The inertia of the valve gear on the exhaust side was, therefore, fairly considerable, but this engine was never intended to run at high r.p.m., as Dr. Porsche thought the use of 4.36 litres, as compared with the 2.9 litres and 3.3 litres of Alfa Romeo and Bugatti, was in itself an adequate guarantee of sufficient power in 1934, and not until 1937 did any other constructor build an engine of comparable capacity to the succeeding Auto-Union models. A limit of 5,000 r.p.m. was envisaged and the early engines peaked at only 4,500 r.p.m.

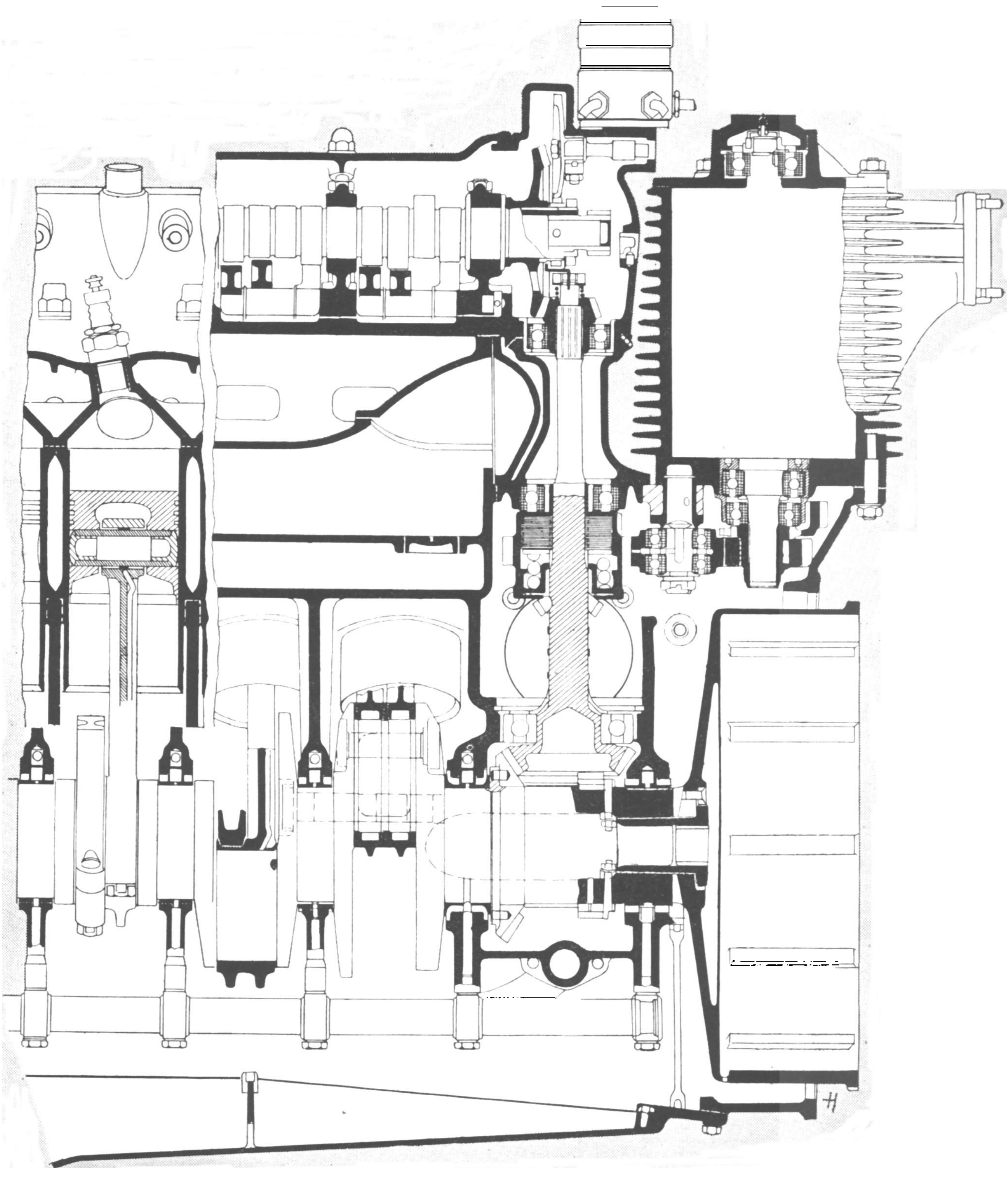
The cylinder heads were in one casting for each block and the cylinder centres staggered by the width of one big end, which amounted to 19 mm. The Roots-type blower was mounted vertically at the rear of the engine, being driven by a train of spur wheels from the camshaft drive. A torque limiting clutch was placed between the driving shaft and the first gear wheel.

The crankshaft for the first engine was a one-piece forging of hardened nickel chrome steel and lead-bronze bearings were used for both the mains and big ends. When the engine was enlarged and the power increased to meet the higher speed of the 1934 Mercedes-Benz cars, these bearings proved inadequate, and in order to use roller bearings for the big ends, the Hirth crankshaft design was adopted. In this, multiple pieces are joined by serrations on the crank pins, the shaft being held together by bolts passing through the eye of the pin, which had a diameter of 68 mm. This permitted the use of one-piece connecting rods running on twenty-eight rollers (5.5 by 5.5 mm.) located in a light alloy cage. The 22 mm. gudgeon pin ran on needle bearings. Lead-bronze was continued for the main bearings, which were 70 mm. diameter, and although the first crankshaft had no counter-balancing, on later designs a degree of counter-weighting was employed.

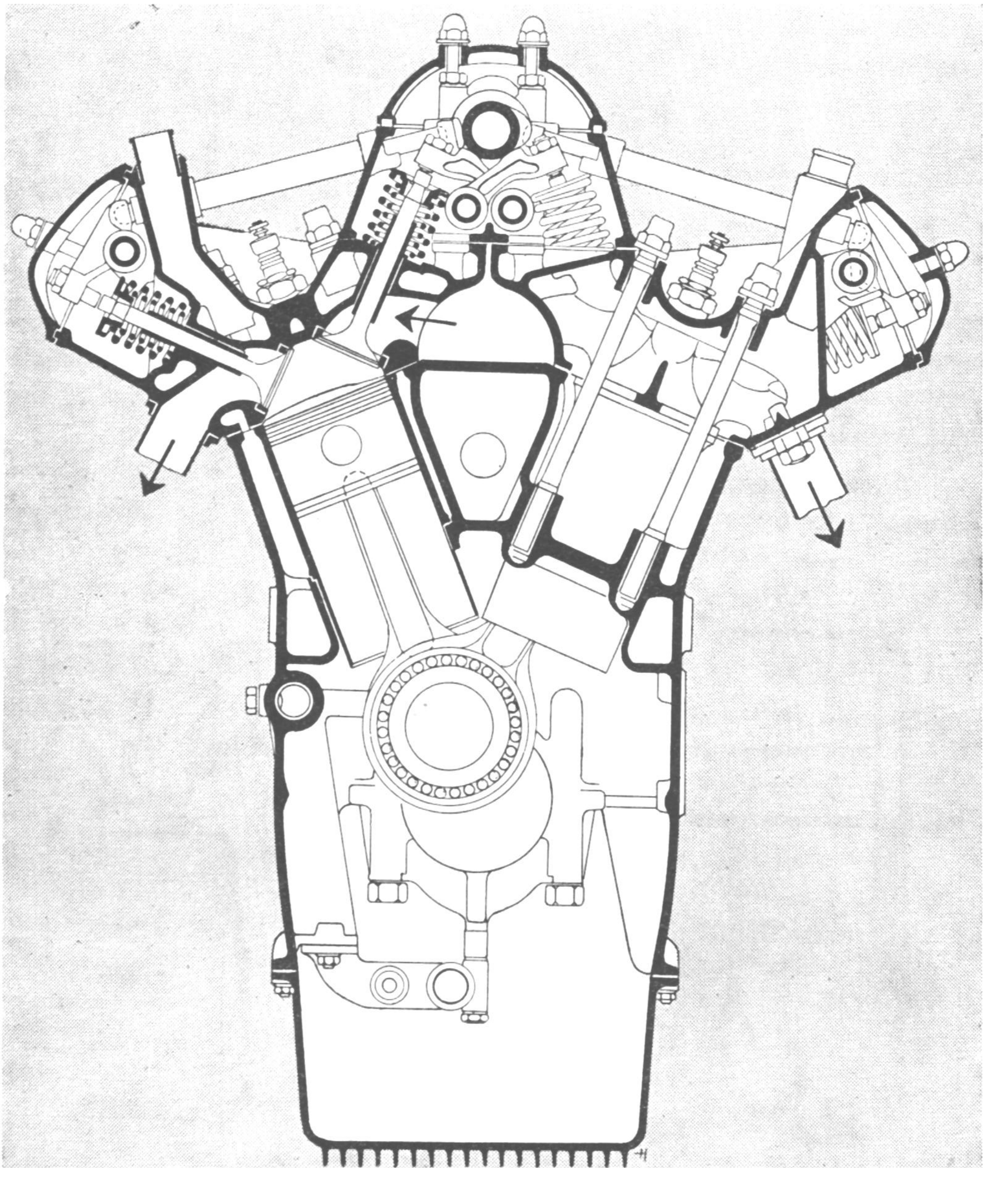
The light-alloy pistons were of conventional design, and it should be noted that the section drawings show the 1934 type, with a flat crown and no internal ribbing. In 1935, when the compression was raised from 7.1 to 9.1, a dome-shaped crown was used and the head heavily ribbed, although the weight was actually decreased.

Despite the depth of the crankcase, lubrication was with a dry sump, the scavenged oil being fed to an oil cooler placed below the radiator at the front of the car and then led into an oil tank immediately ahead of the driver. From there a gravity head was available to the pressure pump which ran at five times engine speed and had an output of 6½ gallons per minute.

As already mentioned, Dr. Porsche's original concept centred around the use of the largest engine possible within the very rigorous weight limit of 750 Kg., and on the first design a boost of only 10 lb. per sq. in. (1.66 ata) was used. Despite successive increases in engine size it was also necessary to raise the b.m.e.p. and boost pressures, and in 1937 the limit of a single-type Roots-type was reached. This type has the advantage of mechanical reliability, absence of wear and can be run without oil, but it is



General arrangement of Auto-Union engines, types A, B and C. Scale 1 : 4.



Cross section of Auto-Union 16-cylinder engine. Scale 1 : 4.

merely a displacer with no internal compression, and the overall efficiency rapidly falls as the boost pressure is raised. The accompanying increase in charge temperature can be offset by the use of fuels with high alcohol content, but these do not seriously reduce the amount of power required to drive the blower, and even with the most careful machining of the rotors and the utmost attention to clearances, the overall engine power may deteriorate if the boost be raised above 13 lb. per sq. in. (1.85 ata); 18 lb. boost (2.2 ata) is the absolute limit for reasonable efficiency.

Alternative superchargers with considerably different proportions of length to diameter of rotor were tried on the C type cars, but there was a negligible difference in their overall performance. Particulars were :

	C. Blower	S. Blower
Rotor length	190 mm.	230 mm.
Rotor diameter	128 mm.	116 mm.
Delivery per blower revolution	2.275 litres	2.860 litres
Blower to engine ratio	2.11:1	2.05: 1
Blower boost	12 to 13.51b. sq. in.	12 to 13.51b. sq. in

In every case the supercharger casing was made in silicon alloy and heavily ribbed to assist cooling and prevent distortion. The end covers were made from the same material and the rotors machined from high tensile steel.

On all Auto-Union engines the superchargers drew mixture from the carburetters and delivered it to the engine. By this means the latent heat of vaporisation of the alcohol-rich fuel lowered the temperature rise in the blower and assisted in keeping small clearances without mechanical seizure. On the 1936 C type engine a mechanical diaphragm pump delivered fuel at 4.3 lb. per sq. in. to a dual choke horizontal Solex carburetter.

The data table and curves in Chapters 28 and 30 indicate that the peak m.e.p. figures for all the Auto-Union engines were obtained at fairly low r.p.m. Subject to adequate maximum power, there are considerable advantages in developing an engine with high torque at low speeds, for acceleration is then considerably improved without excessive gear changing. In this matter, Auto-Union practice diverged markedly from that of Mercedes-Benz. Whereas, however, the 6-litre Auto-Union engine cannot claim to be remarkable for specific output, its power-to-weight ratio gives a very favourable figure indeed. The total weight with clutch came to only 540 lb., and equivalent of 1.08 lb. per b.h.p.

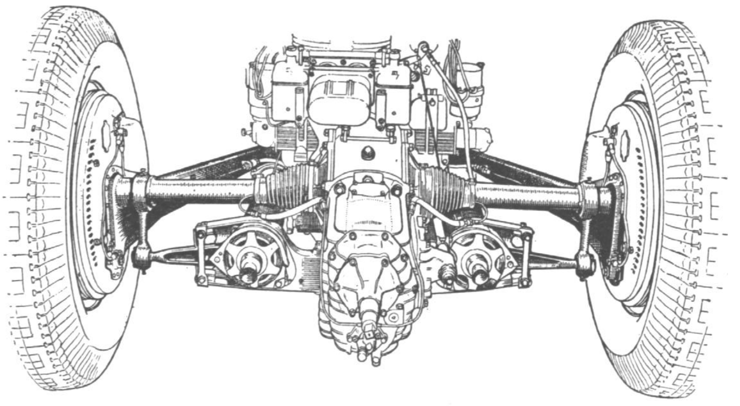
This extremely low figure was the engineer's answer to the endeavour of the A.I.A.C.R. to lower road speed by imposing a weight limit of under 15 cwt., but this figure admittedly excluded some of the heaviest parts of the car. It was only a popular fallacy that the 750 kg. formula resulted in 500 h.p. cars weighing less than 15 cwt. for the dry weight of the Auto-Union complete was 16.2 cwt., and the starting-line weight 6.2 cwt. more, the individual weights being :

Engine 540 lb.	*Fuel 410 lb.	Rear Axle 258 lb.
Accessories 258 lb.	*Driver 175 lb.	*Tyres 158 lb.
Frame 135 lb.	Gearbox 82 lb.	Body 76 lb.
*Wheels 70 lb.	*Oil 70 lb.	*Water 65 lb.
Steering 35 lb.	Springs 23½ lb.	

Total 2,508 lb. (22.4 cwt.).

The items marked with an asterisk, amounting in all to 948 lb., were exempt from the scales, and when deducted left the bare weight for weighing-in purposes at 710 kg.-a margin of nearly 6 per cent within the prescribed limit.

The general arrangement of the Porsche design contributed to this satisfactory state of affairs, but on the other hand the cars were undoubtedly difficult to handle even apart from the special problems raised by their exceedingly high power/weight



Perspective layout of the rear suspension

ratio. With nearly 60 per cent of the weight carried on the rear wheels, and the exceptionally high roll centre at the rear brought about by the use of the swing-axle system, the cars were fundamentally inclined to over-steer, and owing to the extremely forward mounting of the driver the tail could move through a considerable angle before the pilot realised the breakaway point had been reached. He would then find it hard to counteract this lag in his reaction and in addition it was by no means easy to gauge the precise position of the rear end of the car. Cornering, therefore, presented very special difficulties, and although both Varzi and Stuck performed creditably with these cars, only Bernd Rosemeyer really mastered them and was able to use their potential performance to the full.

Acknowledgements.-The author is deeply indebted to Prof. Dr. Ing. Eberan van Eberhorst for supplying facts and drawings of this car and to Robert Braunschweig for the part he played in obtaining them.

RACING RECORD OF C TYPE AUTO-UNION

Date	*Event*	*Course*	*Average Speed*	*Lap Speed*
13/4/36	Monaco G.P.	Monte Carlo	—	56.01 m.p.h.
14/6/36	Eifel Races	Nürburg	72.71 m.p.h.	74.46 m.p.h.
26/7/36	German G.P. . ..	Nürburg	81.8 m.p.h.	85.52 m.p.h.
15/8/36	Coppa Acerbo .	Pescara	86.48 m.p.h.	89.04 m.p.h.
23/8/36	Swiss G.P. ..	Berne	100.45 m.p.h.	105.42 m.p.h.
13/9/36	Italian G.P. .	Monza with chicanes	84.59 m.p.h.	87.18 m.p.h.
5/7/37	Vanderbilt Cup ..	Roosevelt Field	82.56 m.p.h.	—
11/7/37	Belgian G.P.	Spa	104.87 m.p.h.	107.7 m.p.h.
15/8/37	Coppa Acerbo . ..	Pescara with chicanes	87.61 m.p.h.	92.00 m.p.h.
22/8/37	Swiss G.P. ...	Berne	97.8 (4th)	106.8 (P)
26/9/37	Czechoslovak G.P. ..	Brno	(3rd)	92.8 m.p.h.
21/10/37	Donington G.P. ..	Donington	82.86 m.p.h.	85.62 m.p.h.

DETAILS OF CAR

MAKE.-Auto-Union
TYPE.-C
YEAR OF CONSTRUCTION.-1936
YEARS RACED.-1936-7
DESIGNER.-Dr. F. Porsche
WHEELBASE.-9 ft. 6½ in.
TRACK, FRONT.-4 ft. 8 in.
TRACK, REAR.-4 ft. 8 in.
HEIGHT TO SCUTTLE.-35 in.
HEIGHT TO DRIVER'S HEAD.-42 in.
MAXIMUM WIDTH.-38 in.
FRONTAL AREA.-10.8 sq. ft.
UNLADEN WEIGHT.-16.2 cwt.
ALL-UP STARTING LINE WEIGHT.-22.4 cwt.
MAXIMUM SPEED.-175 m.p.h. at 5,000 r.p.m. on fifth speed with 10:33 bevels and 7.00 x 19 in. tyres
SPEED ON INDIRECT GEARS.-157 m.p.h. on fourth; 137 m.p.h. on third; 113 m.p.h. on second; 75 m.p.h. on first
H.P. PER SQ. FT.-48
H.P. PER TON UNLADEN.-585
H.P. PER TON LADEN.-430
BORE.-75 mm.
STROKE.-85 mm.
S./B. RATIO.-1.13:1
No. OF CYLINDERS.-16
CAPACITY.-6,006 c.c.
PISTON AREA.-109.5 sq. in.
B.H.P.-520 at 5,000 r.p.m.
H.P. PER SQ. IN.-4.75
B.M.E.P.-230 lb. sq. in.
PISTON SPEED FT./MIN.-2,900
CYLINDER HEAD.-Light alloy detachable for each bank of cylinders
VALVES No.-Two per cylinder
VALVES ANGLE.-90 degrees
VALVE AREA.-Inlet 23.7 sq. in.
Exhaust 20 sq. in.
CYLINDER BLOCK.-Aluminium casting in unit with crankcase. Wet steel liners
FUEL.-Petrol-Alcohol mixture
CARBURETTER.-2 Solex
SUPERCHARGER.-Roots driven at engine speed x 2.11
MANIFOLD PRESSURE.-13 lb. sq. in. (1.85 ata)
IGNITION.-Two magnetos
PLUGS No.- 16
PLUGS LOCATION.-offset on centre line of head
CRANKCASE.-Light alloy casting embracing water jackets, split below centre line of bearings. Light alloy sump added to base.
CRANKSHAFT.-Built-up Hirth, counterbalanced
MAIN BEARING No.-10
MAIN BEARING TYPE.-Lead-bronze
BIG-END TYPE.-Roller
LUBRICATION.-Dry sump
CAMSHAFT LOCATION.-Between cylinder heads on centre line of engine
VALVES OPERATED.-Inlet valves direct with followers; exhaust valves by transverse push rods and rockers
CAMSHAFT DRIVE.-Vertical shaft and bevel gears
CAMSHAFT DRIVE LOCATION.-Rear of engine
CLUTCH.-Multi-plate
GEARBOX LOCATION.-In unit with engine behind rear axle centre
GEAR RATIOS.-2.84, 3.19, 3.22, 4.25, 6.6 using 10:33 bevels; 10:30 optional
TRANSMISSION.-By shaft running beneath bevel gears to all indirect five-speed box; final crown-wheel and pinion with optional ratios 3.0 or 3.3:1. Swinging half-shafts (with Porsche joints and torque arms) take drive to rear wheels
FRAME.-Tubular
FRONT SUSPENSION.-Porsche type trailing links with torsion bars
REAR SUSPENSION.-Swing axle with torsion bars
SHOCK ABSORBER TYPE.-Friction
BRAKE SYSTEM.-Lockheed two leading shoe with double master cylinders
BRAKE DRUM DIAMETER.-16.4 in.
BRAKE DRUM WIDTH.-1.97 in.
SQ. IN. PER TON LADEN.-362 sq. in.
WHEELS.-Rudge detachable
TYRES.-Continental, 5.25 x 17 front; 7 x 19 rear or 7 x 22 optional

EXAMPLE -No. SIXTEEN

The 1937 Mercedes-Benz, Type W.125

TO put the W.125 Mercedes-Benz into proper perspective it is essential to have an understanding of the affect on design of changes in formula, and also the time lag between commencement of a design and its appearance in racing.

The formula limiting maximum weight to 750 Kg. (agreed in October, 1932) had validity in the years 1934, ‘35 and ‘36, but by the end of 1935 it was recognised that it had completely failed to check the power and speed of racing cars. The problem of a revised ruling for the years 1937, ‘38 and ‘39 then came under review, and on February 13th, 1936, the A.I.A.C.R. accepted, as a basis for these years, a proposal by the Bureau Permanent International des Constructeur d’Automobiles an organisation which represented all the constructors, including, of course, those engaged in active racing. They suggested that weight should be fixed at a minimum in place of a maximum figure, and be simultaneously related to cylinder volume The maximum engine size was to be 3,460 c.c. with supercharger or 4,500 c.c. unsupercharged, and using either of these sizes of engine the minimum weight was 850 Kg. or 16.7 cwt. However, insofar that the 850 Kg. minimum included wheels and tyres, whereas the 750 Kg. maximum excluded these components, this aspect was of no great technical significance. Novelty lay in assessing a supercharger as worth an extra 30 per cent in engine capacity.

This proposal was never effective, because in September, 1936, the A.I.A.C.R. decided to raise the unblown capacity ratio from 1.3 to 1.5 to 1, to retain the minimum weight limit of 850 Kg. for the largest size of engine, to accept 4,500 c.c. as the maximum capacity unblown, and thus to limit supercharged engines to 3,000 c.c. Seven months had passed between the date of the original proposals and their adoption in modified form, and to spare constructors the almost impossible task of producing new designs within six months, it was agreed to extend the 1934-6 regulations for a further year and to embrace the new rules for the seasons 1938, ‘39 and ‘40.

The abortive February formula is not, however, of mere academic interest for it led to the Mercedes-Benz W.125 being originally planned for an engine capacity of under 3½ litres, a figure corresponding with the original straight-eight M.25 series engine produced in 1934. This makes it the more interesting that the car was designed to have a wheelbase 3 in. longer than the 1935 W.25B type and 1 ft. longer than the 1936 W.25E type, a change dictated by reasons of stability and road holding, but highly convenient when it was decided to fit an enlarged engine for the " extended " year of the old formula. It is nevertheless remarkable that it was possible to install 5.66-litre engine with nine bearings, which was 5½ in. longer and 45 lb. heavier than the original 1934 type, and still keep within the original 750 Kg. weight limit.

The new engine developed over 600 b.h.p. and these cars represent an all-time high from the viewpoint of h.p. per ton and per sq. ft. of frontal area.

The new car was based upon a very stiff frame made from nickel-chrome molybdenum tube, a material chosen for its remarkable resistance to fatigue and ease of manipulation. The side members consisted of a sheet only 1.5 mm. thick formed into oval section tubes 5½ in. deep and 3½ in. wide, the details of which are disclosed in a

EXAMPLE No. SIXTEEN

The 1937 Mercedes-Benz, Type W125

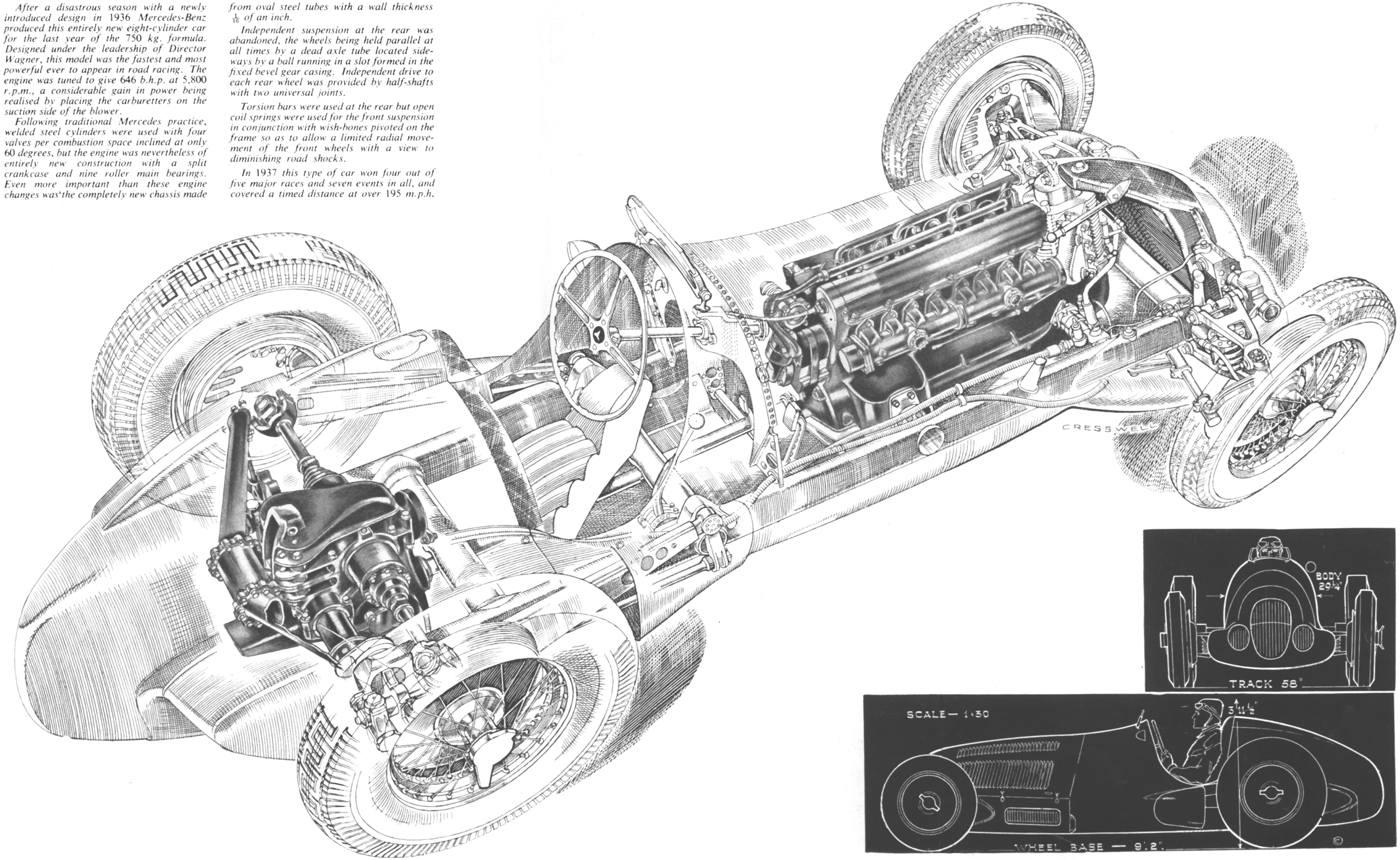
After a disastrous season with a newly introduced design in 1936 Mercedes-Benz produced this entirely new eight-cylinder car for the last year of the 750 kg. formula. Designed under the leadership of Director Wagner, this model was the fastest and most powerful ever to appear in road racing. The engine was tuned to give 646 b.h.p. at 5,800 r.p.m., a considerable gain in power being realised by placing the carburetters on the suction side of the blower.

Following traditional Mercedes practice, welded steel cylinders were used with four valves per combustion space inclined at only 60 degrees, but the engine was nevertheless of entirely new construction with a split crankcase and nine roller main bearings. Even more important than these engine changes was the completely new chassis made from oval steel tubes with a wall thickness $\frac{1}{16}$ of an inch.

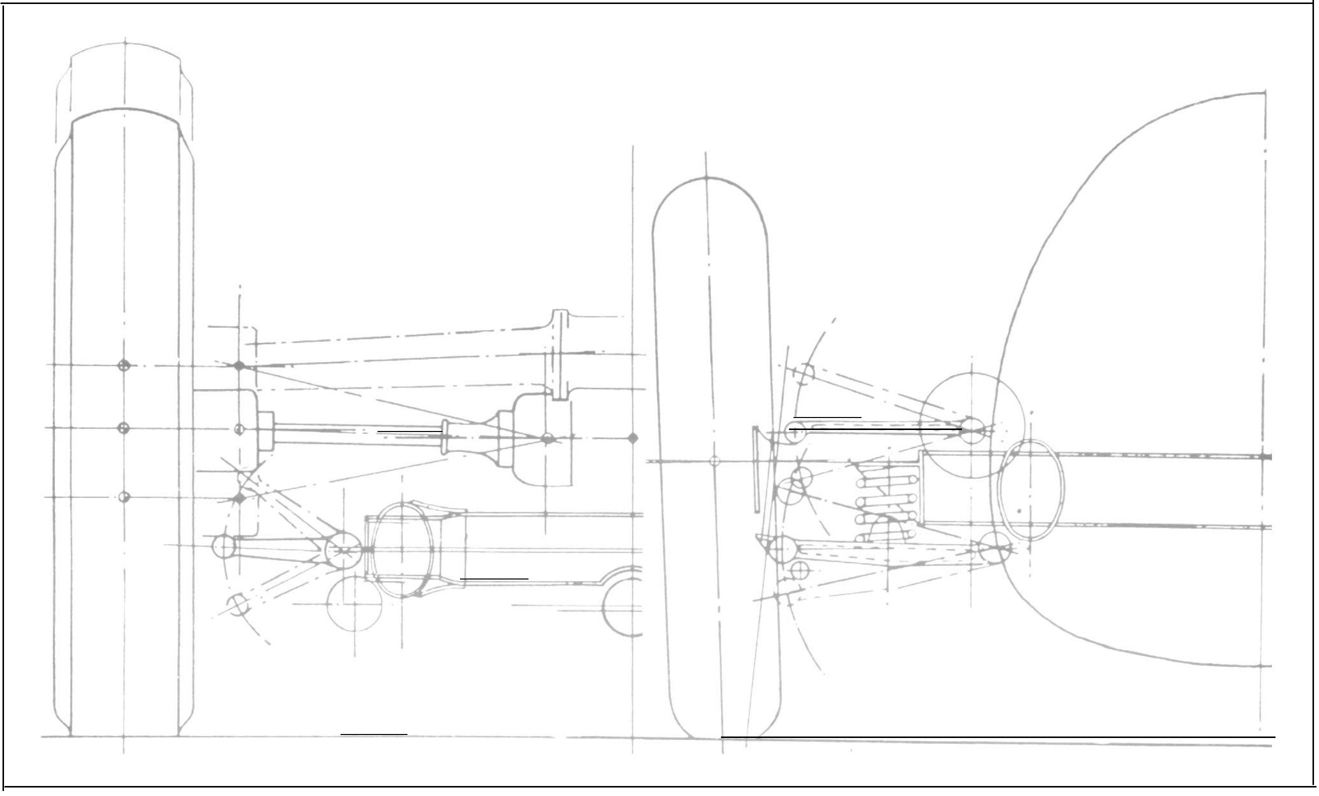
Independent suspension at the rear was abandoned, the wheels being held parallel at all times by a dead axle tube located sideways by a ball running in a slot formed in the fixed bevel gear casing. Independent drive to each rear wheel was provided by half-shafts with two universal joints.

Torsion bars were used at the rear but open coil springs were used for the front suspension in conjunction with wish-bones pivoted on the frame so as to allow a limited radial movement of the front wheels with a view to diminishing road shocks.

In 1937 this type of car won four out of five major races and seven events in all, and covered a timed distance at over 195 m.p.h.



drawing. These side members were braced laterally by four round tubes, all approximately 4 in. in diameter, but actually varying slightly according to their position in the frame. At the rear two closely spaced cross tubes provided a three point mounting



These factory drawings show the front and rear wheel motions and schematic suspension layout, adopted on the 1937 Mercedes-Benz Type W. 125. Scale 1 : 10

for the complete transmission aggregate, at the front the cross tube was extended through the side members to provide the mounting for the independent front suspension system.

On the new car the short wishbones and horizontally enclosed coil springs of the previous models were abandoned in favour of long wishbones with an open coil spring, the design being almost identical with the arrangement employed on the type 500K and 540K production cars since 1934. The wishbones were of unequal length, the top measuring 10 in. between the two pivot points and the bottom 11.8 in., and provided a total movement of 5¾ in. of which 3 in. was from normal to full bump position. This was an increase of some 50 per cent upon the travel permitted on the previous design of the cars and the W.125 can justly claim to have pioneered the modern movement toward truly soft independent suspension for racing motor cars.

An interesting refinement is to be found in the immensely long king-pin employed, this extending practically the whole length between the outer ends of the wishbone arms and providing exceptional support against cornering and braking loads. The projection of the king-pin to the ground gives an offset to the tyre centre of 1.25 in.

Great care was taken to ensure accurate steering geometry. A primary track rod swung on arms mounted on the frame, there being short rods extending on each side, swinging approximately (but not exactly) around the arc struck by the wishbones.

Steering was through a worm and nut box mounted immediately behind the engine with a long push-pull rod running down the exhaust side of the engine.

It has been seen that the front suspension involved the application of known schemes ; the 1937 design for the rear suspension was, however, a complete breakaway from convention, so far as racing cars were concerned. As power and speed rose the simple swing axle employed on the 1934 cars was found to be inadequate mechanically and undesirable geometrically. In particular, the high roll centre provided by a swing axle resulted in too great a proportion of the roll couple of the car being taken on the rear wheels. The type W.25 was, in consequence, an inherent over-steerer, a particularly undesirable feature on a car with over 400 b.h.p. per ton in which the rear wheels would spin between 50 and 150 m.p.h. on top unless care was exercised by the driver,

Director Wagner, who was responsible for much of the work on these cars, enunciated the doctrine that a rear suspension must fulfil two primary duties, viz : maintain wheels parallel at all times and provide complete freedom from side float. These are characteristics of a well-mounted live axle, but the unsprung weight of such a component was thought to be intolerable on a racing car. There remained a form of construction, designed by either Trepardoux or Bouton for the Count De Dion before the turn of the twentieth century, which consisted of open shafts driving the wheels through two universal joints from a bevel box mounted on the frame, the wheels being located by a dead tube attached to the hubs.

The first Mercedes-Benz experiments with such a layout were carried out during 1936, but trouble was experiencedwith the splines in the driving shafts, and with the sideways location of the De Dion tube, which was by a projection running between two large rubber rollers.

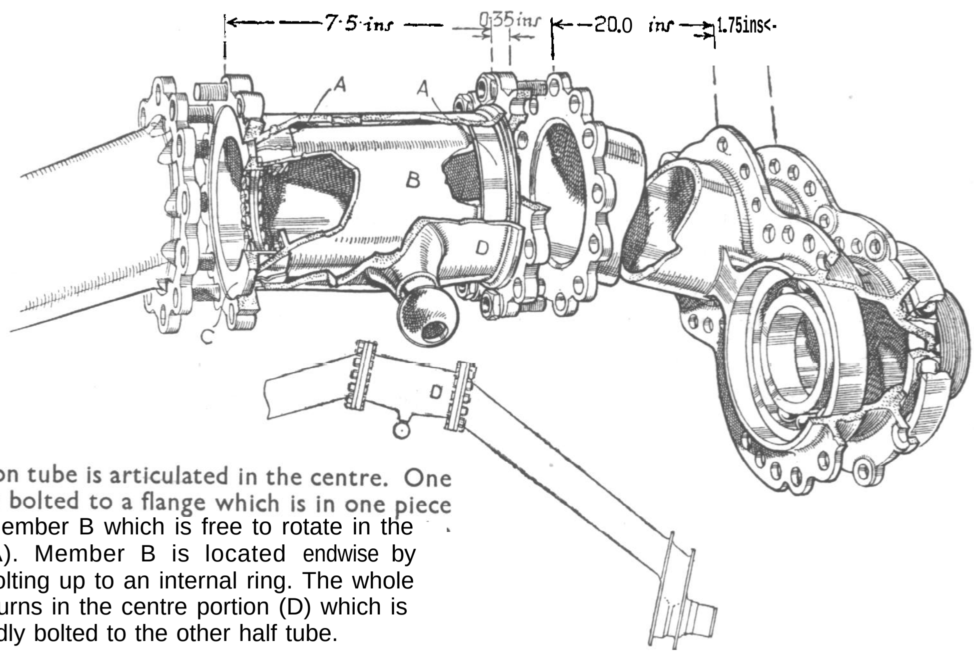
For 1937 an entirely new scheme was devised. The inner universal joints were of true De Dion type, consisting of hardened pins engaging with bronze blocks which in turn fit into hardened steel slots attached to the differential gear. With this arrangement the blocks can have an angular relation to the slots and can also move in and out thereof and splines are thereby avoided. The De Dion tube was located sideways by a hardened steel ball formed in one with the centre portion and running in a long slot formed at the back of the bevel box. This gave the required sideways rigidity. Torque arms were connected to ball joints on the side of the frame, the distance from the hub centre to the ball joints being 36 in.

From this arrangement it follows that as the rear wheels rise and fall they swing about a 36 in. radius imposed by the arms and also that if only one wheel rises this wheel traverses an arc and has an angular relationship to the other rear wheel. This would only be possible by twisting the De Dion cross tube which would then act as an excessively strong torsion anti-roll bar whereby (apart altogether from the severe stresses which would thus be set up) the handling qualities of the car would be impaired.

To relieve the De Dion tube from torsion it was necessary to divide it so that one half could turn in relation to the other, although externally the W.125 De Dion tube appears to be in only three pieces with the centre part having the two long arms bolted directly to it. This is not so, for the centre part includes a highly ingenious oscillating joint, the details of which are clearly disclosed in a drawing. This also shows

the remarkable construction used for the outer "halves" each one of which consists of a side tube and hub machined from a single forging and including varying wall sections and a slight taper from the inner to the outer end.

Each wheel was connected through a 6½ in. lever to a torsion bar 18 mm. diameter and 22½ in. long. These torsion bars were splined at each end, copper plated, and mounted outside the frame, and the arrangement permitted a maximum traverse on the rear wheels of 7 in. with 3½ in. from normal to full bump position. Thus the softness of the front suspension was matched by a corresponding increase in wheel movement on the rear springing as compared with the previous design. The actual rate of the suspension at the back varied with wheel motion as the motion of the link connecting the torsion bar to the wheel offers a decreasing mechanical advantage and raises the rate by some 30 per cent at the full bump position.



The De Dion tube is articulated in the centre. One half tube is bolted to a flange which is in one piece with the member B which is free to rotate in the bushes (A). Member B is located endwise by flange C bolting up to an internal ring. The whole assembly turns in the centre portion (D) which is rigidly bolted to the other half tube.

The use of the De Dion tube at the rear and of nearly parallel movement for the front wheels produced a car with general under-steer characteristics. This gave the driver a much higher degree of control over the car as any required degree of over-steer could always artificially be engendered by spinning the back wheels, there being some 600 h.p. per ton nominally available for this purpose.

The power unit was three point mounted in the frame and, although square to it, the crankshaft was inclined from the horizontal with the propeller shaft continuing this angle so that the centre line of the bevel pinion was much below the centre line of the crankshaft.

The gearbox and bevel drive were developed from the 1936 car (with the requisite modifications for the De Dion drive) and in place of the spur type step-down gears used on the 1934 model the bevel gears were mounted on the central axis of the car 8.8 in. below the wheel centres. Four indirect gears were used, two on each side of the bevels, their shafts lying one above the other and the upper shaft engaging with a pair of spur wheels driving the half shafts through the medium of a Z.F. differential.

This component consists essentially of a cage bolted to the final spur wheel which carries oval shaped " fingers " engaging with a ring of inner recesses connected to one half shaft, and a ring of outer recesses connecting to the other half shaft. The number of recesses carried is slightly different for each shaft and to obtain differential movement between the wheelsthe " fingers " have to pass from one recess into another. Two things follow. Firstly, on a corner the drive is transmitted irregularly to the inner and outer wheels ; second as the difference in speed between the wheels increases, so does the power loss in the differential until, on sharp corners, the efficiency figure may fall to as low as 50 per cent By this means drivers were relieved from the embarrassment of having grossly excessive power at the rear wheels when actually cornering, and from the obligation to use the throttle with the utmost care and delicacy.

Changes in gear ratio could be effected by altering the bevel wheels, the final spur wheels or by changing the gears themselves The lowest final ratio was 4.70:1 overall, a normal ratio was 3.52: 1, and there was a highest possible gear of 3.28: 1. Normal tyre size at the back was 7.00 by 22 with an effective diameter of 36 in., but both 7 by 19 and 7 by 24, with effective diameters of 33.4 in. and 38 in. respectively, were possibilities giving 200 m.p.h. at 5,800 r.p.m., using the highest gear and biggest tyre and 188 m.p.h. and 178 m.p.h. on the two smaller wheels.

The way in which these variations were employed in racing can be realised by comparing the ratios used for the 1937 Monza test runs with the gears used at Berne and Monaco. In the latter race the first and second gear ratios were left unchanged in the box, but the third and top were altered and the lowest gearing employed for the final drive. Resultant ratios were overall: 4.7, 5.95, 6.1 and 9.55: 1. The relation of these gear ratios to road speeds is of some interest and can be set out in a table as follow :

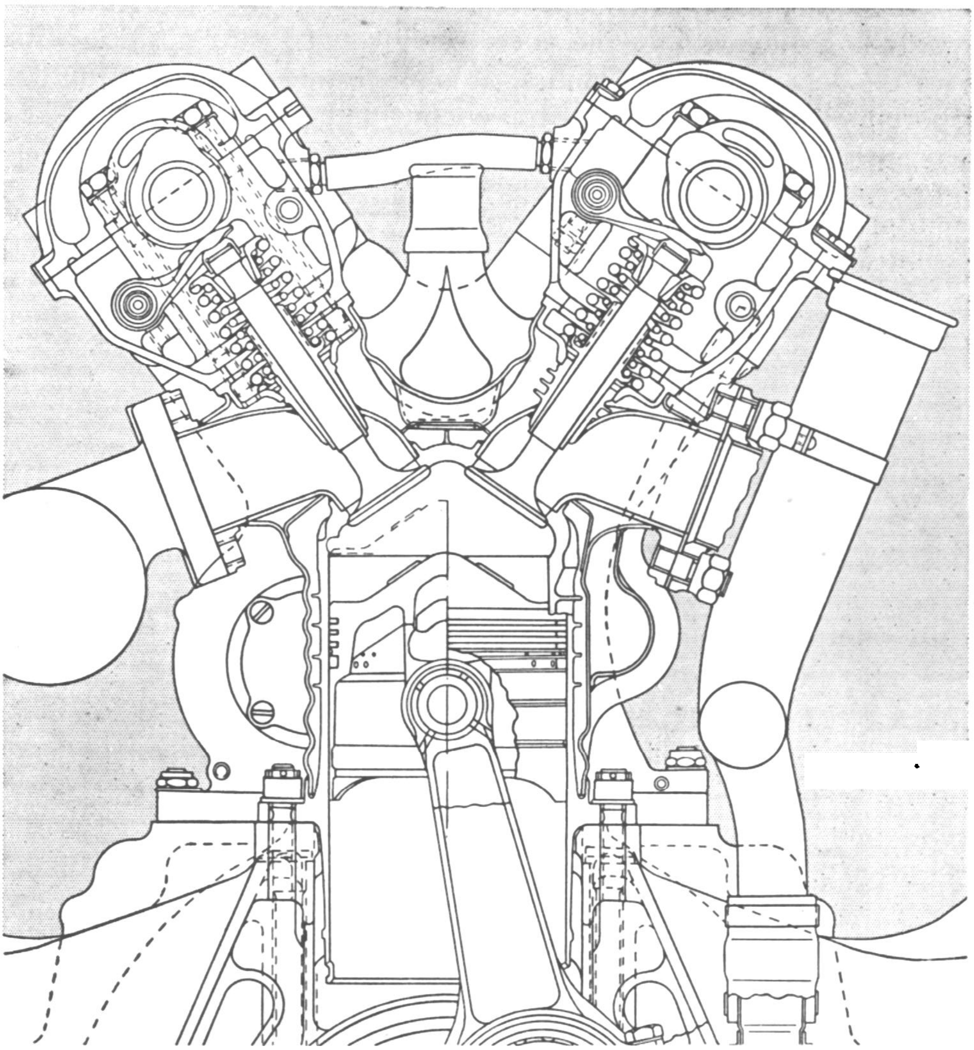
W.125 ROAD SPEEDS AT 5,800 R.P.M.

Course	I	II	III	IV
Monza	m.p.h. 73 (8.0)	m.p.h. 114 (5.15)	m.p.h. 132 (4.45)	m.p.h. 166 (3.52)
Berne	Ditto minus 5 cent by use of smaller wheels			
Monaco	60 (9.55)	93.5 (6.15)	96 (5.95)	122 (4.70)

The right-hand gear lever was provided with a conventional gate, means however being provided to ensure the lever would not jump out of any given position. No handbrake was fitted, reliance being placed solely upon the Lockheed hydraulic brakes with double master cylinders as developed for the prior design. Considerable developments had, however, taken place in the brake shoes, the two leading shoe system being adopted and the brake drum diameter increased with light-alloy drums having inserted liners.

Weight distribution was another factor greatly aiding the stability of the cars. On the type W.125, Director Wagner made great efforts to put the polar moment as high as possible by massing the weight of the engine and the gear-cum-bevel box aggregate at opposite ends of the frame, as is particularly well shown in the perspective drawing of the car.

The 5.66-litre engine, designated the M.125, followed the main principles previously established, but had entirely new detail design. Cylinders made from steel forgings with welded-up ports and welded water jackets in blocks of four were retained and there were no substantial changes in the valve gear layout, angle of valves, camshaft drive, piston and connecting rod design. Split roller bearings were continued for big-end and main bearings, together with a one-piece crankshaft, but the latter was designed to



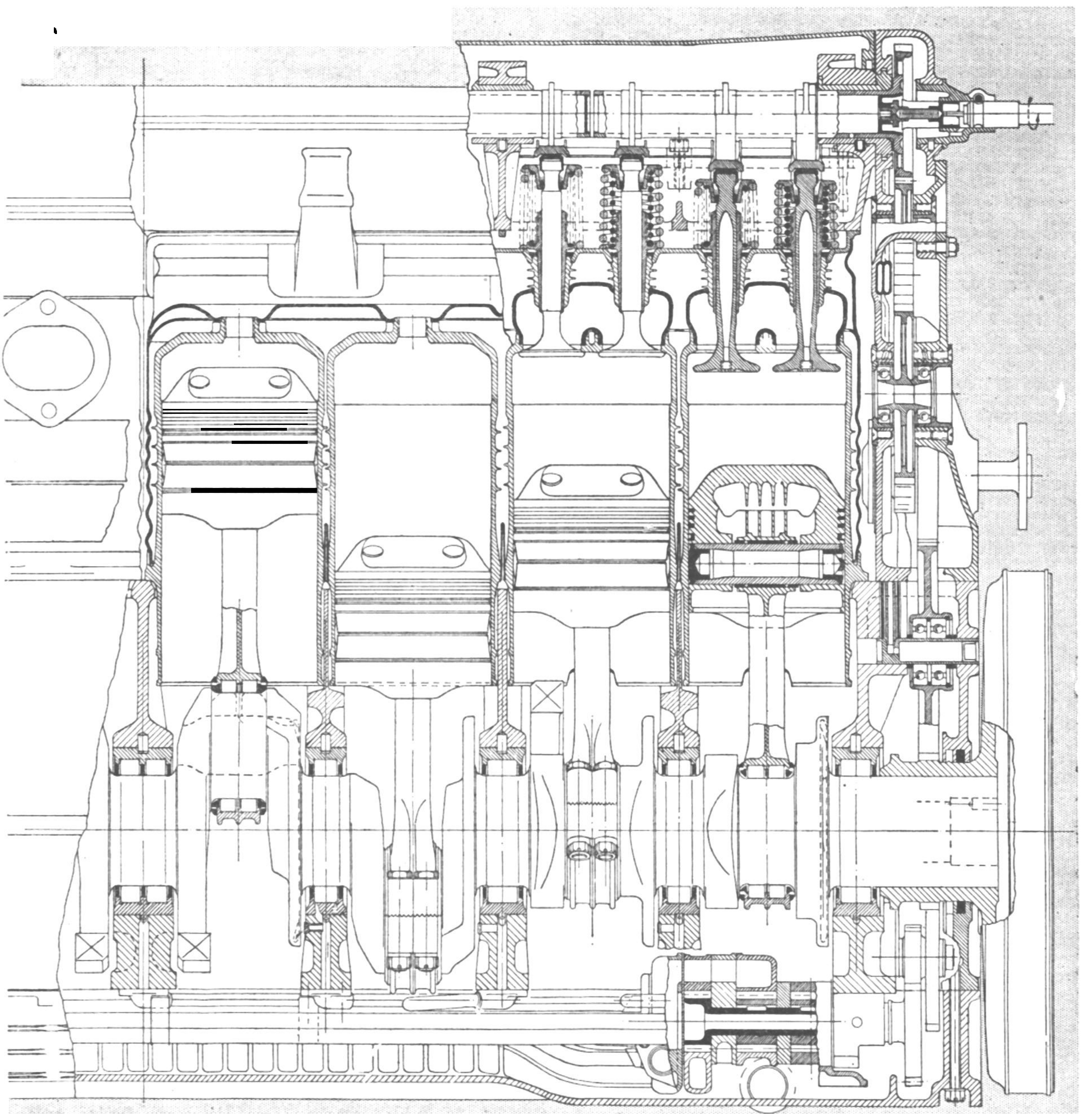
The I937 Type W.125 racing engine bears an almost startling resemblance to World War I Mercedes aviation engines, the most notable change being the use of two overhead camshafts. This drawing shows clearly the welded-up constructlon of the cylinder block which is connected to the exceedingly deep crankcase by through-bolts, which also retain the bottom halves of the nine main bearing caps. Scale I :3.

have nine main bearings inserted into an open bottomed crankcase, the bearing caps being retained by through bolts which also held the cylinder block on to the crankcase. Any loss in lateral stiffness was made good by set screws with heads external to the crankcase and threads engaging with the side of the main bearing cap.

Engine dimensions were increased to 94 x 102 mm., and all the internals of the engine stiffened substantially. The diameter of the big ends was raised from 53 mm. to 63 mm., and that of the main bearings from 63 mm. to 66 mm The width of the big ends was increased from 30.5 mm. to 33 mm., and in place of the main bearings having a uniform width of 29 mm., the centre bearing was made 35 mm. wide, and the other bearings 25 mm. wide . The main bearings employed 10 by 18 mm. rollers and the big ends double rollers 8 by 10 mm This resulted in a substantially bigger engine, the length

of the crankshaft, for instance, being increased by some 5½ in. By very careful attention to detail, however, the weight increase amounted to less than 45 lb. compared with original 3.36-litre layout.

Inspection of the lateral and cross-section drawings of the engine reveals the notable continuation of Mercedes tradition in the detail layout. Points of particular interest are the way in which the cylinders were deeply spigoted into the crankcase and provided with stiffening ribs around their circumference The. water jackets were corrugated to allow for differential expansion, the ports being welded into position with welded-in supports for the detachable valve guides. It is interesting to note that on the exhaust side the supports were finned to supply extra cooling and that the exhaust valves



This longitudinal section of the W.125 engine (scale 1 : 4) gives additional details of the cylinder construction and shows the split housings for the rollers used for both main and big-end bearings.

were hollow so as to permit sodium cooling. The inlet and exhaust valves had a common diameter of 39 mm. with a total valve area of 29.6 sq. in., the output per square inch of valve area thus being 21.8 b.h.p. The relation of valve area to piston area was 0.30 : 1, the lift on the valves being held at 8.5 mm. The cross-sectional drawing also indicates the very steeply domed pistons which gave a compression pressure (without boost) of 165 lb., equivalent to a nominal compression ratio of approximatel 6:l.

It will be seen that the piston crown was exceptionally thick (approximately 8 mm.) and that four projections were machined on the head, these registering with the centre of the valve ; hence, should the valves stick for any reason there was some chance of their being returned to their seat without being bent by impact with the piston.

The gudgeon pin ran on a plain bronze bush let into the steel connecting rod. The diameter of the pin was only 24 mm., that is to say less than 25 per cent of the piston diameter, which is a remarkably low proportion.

The connecting rod itself was a nearly parallel H-section with ribs running from the eye of the big end up into the rod itself. The faces of the two halves of the big end were serrated and held in place by four bolts.

Lubrication was on the dry-sump system, a large oil tank being placed between the frame and the crankcase on the left-hand (i.e. on the exhaust) side of the engine. The sump consisted of a shallow light-alloy casting bolted on to the bottom of the unusually deep crankcase. Gear-type oil pumps were driven by a long shaft projecting forward from the rear-end camshaft drive.

A right-angle drive was provided at the front end of the engine with the water pump mounted on the left-hand exhaust side and a fuel pump on the opposite side. The latter drew fuel from the rear tank through a flexible pipe 7/8 in. o.d. and had a return pipe of equal size, a spill valve despatching surplus fuel back into the tank. In conformity with the usual practice on this series of engines the Roots blower was mounted vertically in front of the engine and driven by bevel gears.

Changes, however, were made from the M.25 series, in which rotor diameters of 106 mm. had been used with successive enlargements of up to 255 mm. in length. On the M.125 the rotors were also 255 mm. long, but increased in diameter to 185 mm., giving a theoretical delivery of 2 litres per revolution. At the same time, however, the blower speed was raised to engine speed by 2.78:1, giving a boost pressure from 10 to 12 lb. per sq. in.

For the Eifel Races of 1937 the cars were run with the long-established Mercedes arrangement of the supercharger supplying pressure air to two twin choke carburetters mounted close to the cylinder block. Although such a scheme offers complete freedom from liquid deposition of fuel even when using extremely rich alcohol mixtures and may possibly give better inter-cylinder distribution it presents other serious problems, particularly air delivery temperatures which lead to distortion of the rotors and casing, which lead in turn to excessive clearances with impaired volumetric efficiency at low engine speeds. As far back as 1924 the Sunbeam Co. had realised the merits of passing fuel/air mixture through the blower and within two years all constructors, other than Mercedes-Benz, had followed this practice. Thirteen years elapsed before this company decided to fall into line but the cars running in the Vanderbilt Trophy on July 5th, 1937; had suction carburetters and these were retained for subsequent events..

The marked effect of this change in the carburation system can be seen by comparing the curves relating b.m.e.p. to piston speed on the M.125 engine and M.25B engines (*vide* Chapter 27). In particular it will be seen that at 2,000 f.p.m. there is an increase of over 18 per cent. in b.m.e.p., a gain following directly on the lowered overall temperature of the ingoing charge, derived from the latent heat of vaporization of the fuel. This was Standard Oil Co.'s W.W.

1937 FUEL FORMULA

Methyl alcohol 86.0 ; Acetone 8.8 ; Nitrobenzene 4.4 ; Sulphuric ether 0.8.

It is not uninteresting to make comparison between the power obtained on this fuel and with 50-50 petrol/benzole mixture. Using two normal fixed choke D-B type carburetters on the suction side of the blower the figures are as follows :

GAIN IN B.H.P. WITH ALCOHOL FUEL

R.P.M.	*B.H.P. 50/50*	*B. H.P. W. W.*	*Gain %*
1,500	147	163.5	11.3
2,000	224	238	11.7
3,000	360	390	8.5
4,000	452	492	9.0
5,000	515	555	8.0
5,500	534	572	7.0
5,800	545	568	4.2

These outputs, for 3 minutes duration, were eclipsed by the use of the " Schiebervergaser. " The " Schiebervergaser " (developed by Herr Scheerer) consisted of a double choke, double jet assembly to which was added a barrel-type throttle which disclosed a very large jet. This third portion of the assembly was used only on wide-open throttle, in which condition the consumption is increased to approximately 2 lb/b.h.p. hour, but with very large gains in power. Thus :

GAIN IN POWER WITH " SCHIEBERVERGASER "

R.P.M.	*B.H.P.*	*B.H.P. Gained*	*B.H.P. Gained %.*
1,500 – – – – – – –	170.5	7	5
2,000 – – – – – – –	248	10	4
3,000 – – – – – – –	406	16	4
4,000 – – – – – – –	525	33	7
5,000 – – – – – – –	610	55	9
5,500 – – – – – – –	625	53	9
5,800 – – – – – – –	646	78	14

The progressive advantage with increasing speed is particularly notable and it is safe to say that no road racing car has ever developed more power than the Mercedes type W.125. One car was timed at 193 m.p.h. on the Spa Circuit, but given a sufficiently high back axle ratio there is no reason to doubt that they could exceed 200 m.p.h. by a useful margin.

Acknowledgements.-Every assistance has been given to the author and artist by the constructors and, in particular, Directors Wagner and Hoppe, Herr Scheerer, and racing mechanic Müller.

DETAILS OF CAR

MAKE.-Mercedes-Benz
TYPE.-W.125
YEAR OF CONSTRUCTION.-1937
YEAR RACED.-1937
DESIGNERS.-Dirs Max Sailer and Wagner, Ob. Ing., Hess and others
WHEELBASE.-9 ft. 2 in.
TRACK FRONT.-4 ft. 10 in.
TRACK REAR.-4 ft. 7 in.
HEIGHT TO SCUTTLE.-41 in. (unladen)
HEIGHT TO DRIVER'S HEAD.-47½ in. (unladen)
FRONTAL AREA.-12½ sq. ft.
UNLADEN WEIGHT.-16.4 Cwt.
ALL-UP STARTING LINE WEIGHT.-21.8 cwt.
MAXIMUM SPEED.-200 m.p.h. with highest gear and largest tyre
SPEED ON GEARS.-According to circuit.
Normal.-166 m.p.h. on Fourth ; 132 m.p.h. on Third ; 114 m.p.h. on Second ; 73 m.p.h. on First at 5,800 r.p.m.
H.P. PER SQ. FT.-51.5
H.P. PER TON UNLADEN.-787
H.P. PER TON ALL-up.-595
BORE.-94 mm.
STROKE.-102 mm.
S./B. RATIO.-1.085:1
No. OF CYLINDERS.-Eight
CAPACITY.-5,660 cc.
PISTON AREA.-86 sq. in.
B.H.P.-646 at 5,800 r.p.m.
H.P. PER SQ. IN.-7.52
B.M.E.P.-252 lb. sq. in.
PISTON SPEED FT./MIN.-3,900
CYLINDER HEAD.-Integral steel
VALVES No.-Four per cylinder
VALVES ANGLE.-60 degrees
VALVE AREA.-Inlet 29.6 sq. in.
VALVE AREA.-Exhaust 29.6 sq. in.
CYLINDER BLOCK.-Forged steel barrels welded together in sets of four with sheet water jackets.
FUEL.-86 per cent Methyl/Alcohol mixture
CARBURETTERS.-One Mercedes-Benz with triple choke tube, and twin-float chamber
SUPERCHARGER.-One Roots at 2.78 engine speed
SUPERCHARGE PRESSURE.-12 lb. boost (1.8 ata.)
IGNITION.-One Bosch magneto
PLUGS No.-Eight
PLUGS LOCATION.-Centre of head
CRANKCASE.-Two-piece light alloy split below centre of main bearings.
CRANKSHAFT.-One-piece counterbalanced
MAIN BEARING No.-Nine
MAIN BEARING TYPE.-Roller
BIG END TYPE-Roller in split housing
LUBRICATION.-Dry sump
CAMSHAFT No.-Two
CAMSHAFT LOCATION.-In head
CAMSHAFT DRIVE.-Train of gears
CAMSHAFT DRIVE LOCATION.-Rear of crank
CLUTCH.-Single plate
GEARBOX LOCATION.-In unit with bevel box
GEAR RATIOS.-3.52, 4.45, 5.15, 8.0
All the above ratios could be varied with circuit.
TRANSMISSION.-Open propeller-shaft inclined to bring bevels 8.8 in. below centre line of hubs. All indirect gearbox with shafts mounted transversely driving exposed half-shafts with double universal joints through spur wheels and Z.F. differential
FRAME.-Oval tube
FRONT SUSPENSION.-Independent to each wheel with wishbones and open coil springs
REAR SUSPENSION.-De Dion type with torsion bar springs
SHOCK ABSORBER TYPE.-Hydraulic
BRAKE SYSTEM.-Lockheed hydraulic
BRAKE DRUM DIAMETER.-15¾ in. internal
BRAKE DRUM WIDTH.-2-3/16 in. front, 3 in. rear
SQ. IN. PER TON LADEN.-290 sq. in.
STEERING.-Worm and nut, 2¼ turns lock to lock
WHEELS TYPE.-Rudge
TYRES FRONT.-5.25 by 17 Continental
TYRES REAR.-7 by 19 Continental ; 7 x 22 or 7 x 24 optional

RACING RECORD OF TYPE W.125

Date	*Event*	*Course*	*Average Speed*	*Lap Speed*
13/6/37	Eifel Races	Nürburg Ring	82.2 m.p.h. (2nd)	84.8 m.p.h.
11/7/37	Belgian G.P.	Spa	102.2 m.p.h. (3rd)	108.8 m.p.h.
2/10/37	Donington G.P. . .	Donington	82.57 m.p.h. (2nd)	85.62 m.p.h.
25/7/37	German G.P.	Nürburg Ring	82.77 m.p.h.	85.56 m.p.h.
8/8/37	Monaco G.P.	Monte Carlo	63.27 m.p.h.	66.8 m.p.h.
22/8/37	Swiss G.P. . . .	Berne	98.55 m.p.h.	107.14 m.p.h.
12/9/37	Italian G.P.	Leghorn	81.5 m.p.h.	84.5 m.p.h.
26/9/27	Czechoslovak G.P. . .	Brno	85.97 m.p.h.	94.89 m.p.h.

EXAMPLE No. SEVENTEEN

Mercedes-Benz Type W.163

IN September, 1936, the A.I.A.C.R. agreed that racing for the years 1938, '39 and '40 should be governed by a sliding scale relationship between a minimum weight and a maximum engine capacity. The upper limit of cylinder volume was set at 3-litre supercharged and 4½-litre unsupercharged, and cars with either of these size of engines had to weigh not less than 850 Kg. or 16.7 cwt. with wheels and tyres.

The new formula was designed to limit racing car performance. In this it was admittedly successful, but the art of the designer was so exercised that the reduction in sheer speed was less than might have been anticipated, and in 1939 the smaller cars were as fast on a circuit as the 650 b.h.p. models built two years previously.

Performance was sustained in the face of reduced engine capacity by increasing piston area, r.p.m. and supercharge pressure (that is to say by maintaining as far as possible the weight of air handled per minute), by reducing the various resistances and finally by improving braking and road holding.

By using twelve cylinders in V formation in place of eight cylinders in line piston area fell by only 26 per cent, although cylinder volume was reduced by 47 per cent as between 1937 and 1938. Engine r.p.m. were raised from 5,800 to 7,800, i.e. by 35 per cent, and the absolute manifold pressure from 27 lb. per sq. in. to 34 lb. per sq. in., i.e. by 26 per cent. The net effect of all these changes was a drop in power of some 30 per cent.

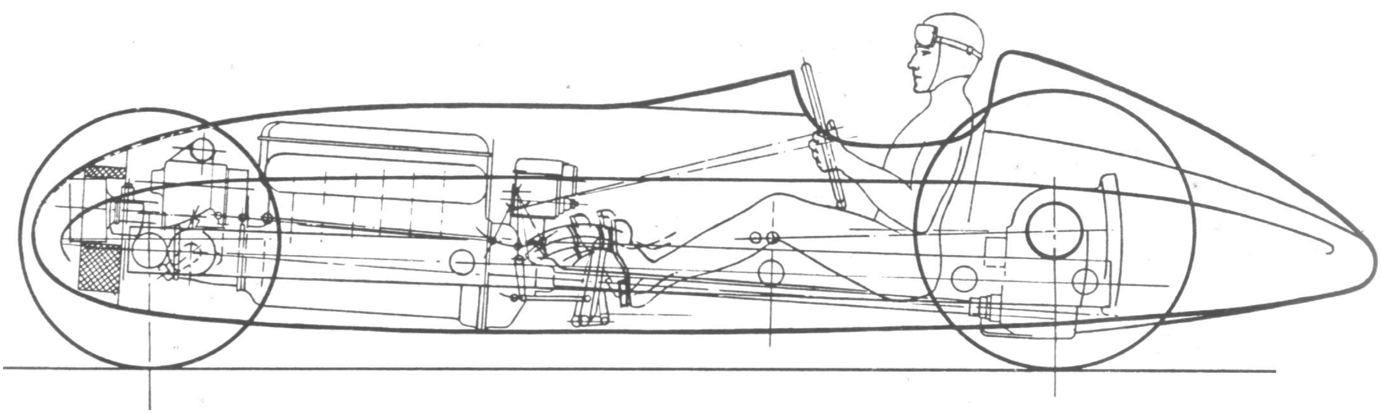
The formula limited the extent to which this reduction in power could be offset by changes in chassis design or body form, for the minimum weight limit prevented the h.p. per ton factor being adjusted to meet the lower gross output and a minimum body width of 85 cm. (339 in.) prevented any substantial reduction in frontal area.

The form of the body was refined with a view to reducing drag, but as the total wind resistance (wind and tractive losses) of the tyres accounts for at least half the power required to drive the car at high speeds it is obvious that no practical changes in body form could produce any large change in overall drag. Experience with the short chassis 1936 car had already indicated paramount need for softer springing and the highest possible polar moment of inertia, and on fundamental grounds it was obviously desirable that soft springing should be coupled with the lowest possible centre of gravity.

Keeping all these factors in mind the Mercedes-Benz design department had a general scheme for the 1938 3-litre type 154 on the drawing board by March, 1937. A completed car was ready for test at Monza twelve months afterwards in March 1938 The type W.163 was a slightly modified type 154 used for the 1939 season and a broad description covers both models.

The 5.6-litre type W.125 had proved a highly successful design, particularly from the viewpoint of road holding and general control, but in order to meet the particular requirements which have been specified above the height of the 3-litre car

was very much reduced by decreasing the stroke from 102 mm. to 70 mm. and placing the cylinders in V formation. The top of the engine was brought within 29 in. from the ground at its highest point at the front of the car. In the mid part of the car the seat was dropped so that the top of it came only 9¼ in. from the ground (an arrangement made possible only by a substantial change in the transmission arrangements). As a consequence of these two modifications it became possible to lower the height of the scuttle from 41 in. to 34½ in. These changes did not substantially affect the frontal area as the new design was much wider than its predecessor, but they did enhance the



The low overall height of the V.12 engine can be seen in this drawing which was produced in 1937 during the project stage of the 3-litre design.

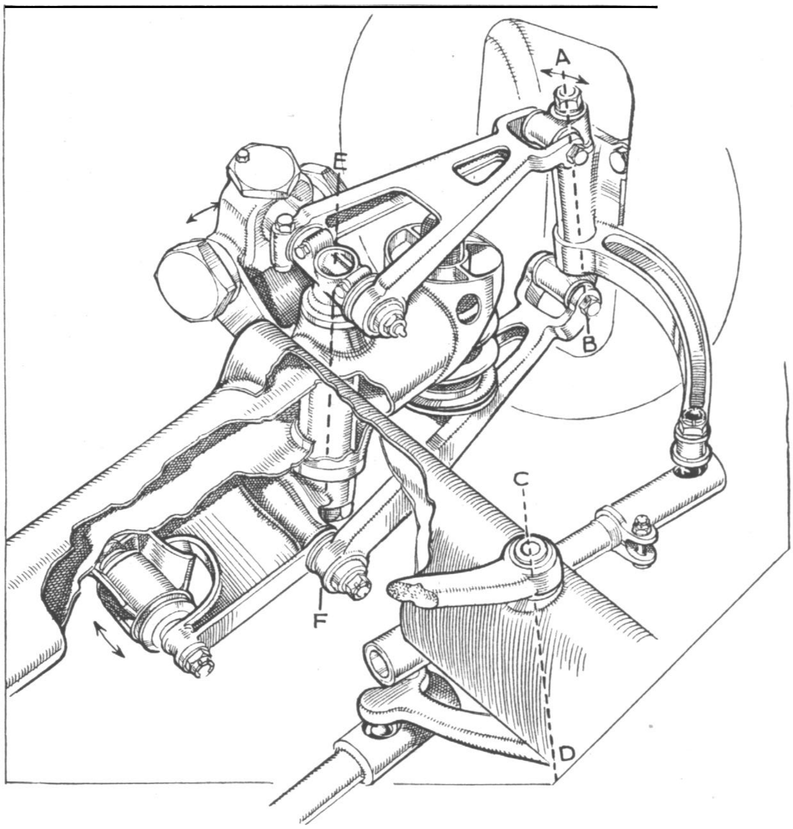
general stability. The frame and suspension of the 3-litre cars were almost identical with the 1937 units. The wheelbase was reduced by approximately 2½ in., the track remained unaltered and the frame was an identical conception comprising oval tubes (130 mm. deep and 90 mm. wide at the largest section), cross-braced with four round tubes. The construction was fully welded in nickel-chrome molybdenum steel 14 mm. thick, and the total weight was approximately 1 cwt.

The rear suspension units, that is to say De Dion cross tube, suspension levers and torsion bars, were identical with the W.125 which have been previously described in detail, and the front suspension system very similar except that whereas the wishbones on the previous car were offset downwards in relation to the wheel centre, on the later model they were raised so as to be almost equally placed above and below the hub centre.

A detail feature of considerable interest used on all the Mercedes-Benz cars has not yet been fully described and is certainly worthy of comment. Prior to 1934 the fastest cars built by the company had been SSK type with rigid front axle and semi-elliptic springs. These suffered from wheel patter and cure was sought in the " kick shackle " popularised by Packard in America. With this arrangement the front axle was given horizontal float by mounting it on two shackles on one side, the degree of float being limited by a spring.

When wishbone type I.F.S. on the 500K model was introduced in 1934 it was thought wise to retain this anti-shimmy device and in due course the 500K design found its way on to the racing cars.

A detail drawing shows how the inner wishbone bearings are mounted on a pivot attached to the frame with fork extension piece running inboard from the bottom of the pivot. This fork embraces a rubber stop which is designed to permit a latitude of plus or minus a quarter of an inch on the king-pin. This movement was determined empirically by *ad hoc* experiment with various coil spring pressures and it is worth noting that the arrangement was used for both front wheels and that it was necessary



Detail of front suspension referred to on this page.

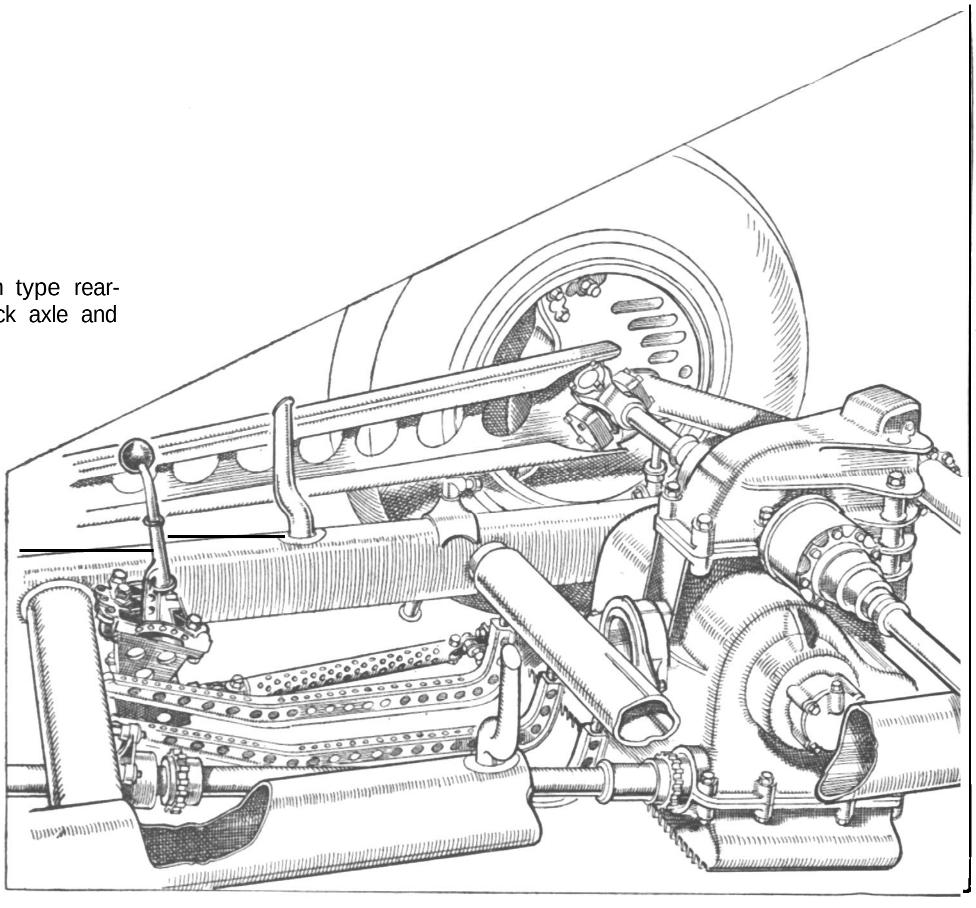
to mount the hydraulic piston-type shock absorbers so that they, also, could move with the wishbones although restrained in the other planes of motion. The whole assembly was mounted on a round cross tube welded into the main oval frame members, the castor angle of 6 degrees being determined by the welding and machining of the pivot point. At the outer end of the wishbones a particular feature is the extreme length of the king-pin, steering being through a short track rod pivoting around the same centre as the bottom wishbone link. This short track rod was linked to a swinging arm which was mounted on another pivot welded into the frame, this being inclined through the same angle as the king-pin so as to give the utmost accuracy in steering.

Referring to the detail drawing it has to be appreciated that AB and EF are both inclined backwards at 6 degrees and that AB is also inclined in the vertical plane to give an offset of 1¼ in. between the projection of the king-pin and the tyre centres. CD matches the angles of AB.

The type W.163 saw a very marked improvement in the design of the brake drums. Two stiff light alloy shoes, each with its individual operating piston, were used in each drum and the diameter and width of the drum were as large as possible within the limits of rim diameter and unsprung weight. The drum itself was made in light

alloy with an inserted steel liner and the novelty in its construction lay in the design of the stiffening and cooling ribs formed around its periphery. On all previous racing cars these ribs had been circumferential, but on the type W. 163 transverse vanes were set at an angle across the rim of the drum and were then encased by a light alloy sheet. By this means air entered, passed from the side of the drum and was expelled centri-

Detail of the De Dion type rear-end with combined back axle and gearbox



fugally through the extreme rim with a considerable lowering of both drum and lining temperature. Air circulation through the inside of the drum was effected by cutting large holes in the side face and arranging that the turbine-like fins had connection with the inner part of the drum and were thus able to draw air right past the friction linings.

The brakes used on the 1939 Mercedes-Benz were an improvement on anything that had previously been used in racing car practice and they contributed not a little to the very high average speeds that these cars could put up on difficult circuits such as the Nürburg Ring.

In addition to improved braking there is no doubt that the measures taken to lower the centre of gravity were effective in increasing the controllability of the cars and the maximum of permissible speed on a given radius curve.

As has been previously mentioned, this low centre of gravity was based upon a major change in the transmission of the car.

On all the eight-cylinder Mercedes-Benz cars the propeller shaft was mounted substantially lower than the wheel hub centres. On the first design (W.25) a pair of step-down gears lowered the shaft by 3½ in. Modification was introduced for 1936

(W25 E) in which the final drive was through a pair of spur wheels, the gears being disposed on each side of the centre line of the car. The drive was thus from the bevels to a primary gear shaft, thence to a secondary gear shaft, and thence to the final spur wheels, and thus lowered the propeller shaft by 9.8 in. The types 154 and 163 saw this expedient carried still further. Five speeds were employed and the bevels were offset by 10.8 in. to the left-hand side of the car, the engine being given a pronounced horizontal inclination so as to provide a straight run for the propeller shaft, which had no universal joints. The engine and propeller shaft line were also inclined downwards so that at the centre point the bevel pinion was 11.2 in. below the centre line of the wheels.

With this arrangement it was possible to bring the seat frame well below the level of the propeller shaft without offsetting the driver in the car and to combine a very low centre of gravity with minimum frontal area and first-class visibility.

The gears were controlled by a right-hand gate and a locking mechanism prevented accidental jumping out of gear. It will be appreciated that the gear ratios could be changed by alteration in the bevel pinions, in all the five gears attached to the primary or secondary gear change, or in the final spur drives. A very large combination of engine to road speeds could thus be provided and a feature of the Mercedes-Benz racing department was a close survey of road circuits leading to an analysis of the required ratios. It is worth setting out in a table some of the principal variations employed during 1939 :

ROAD SPEED AT 7,500 R.P.M. ON W.163

		M.P.H.				
Race	*Tyres*	*I*	*II*	*III*	*IV*	*V*
Pau	7.00-19	37	53	87	107	125
Rheims	7.00-22	77	94	129	150	185
Nürburg	7.00-19	58	104	129	151	188
Berne	7.00-22	59	95	130	152	168
Belgrade	7.00-19	55	89	109	128	141

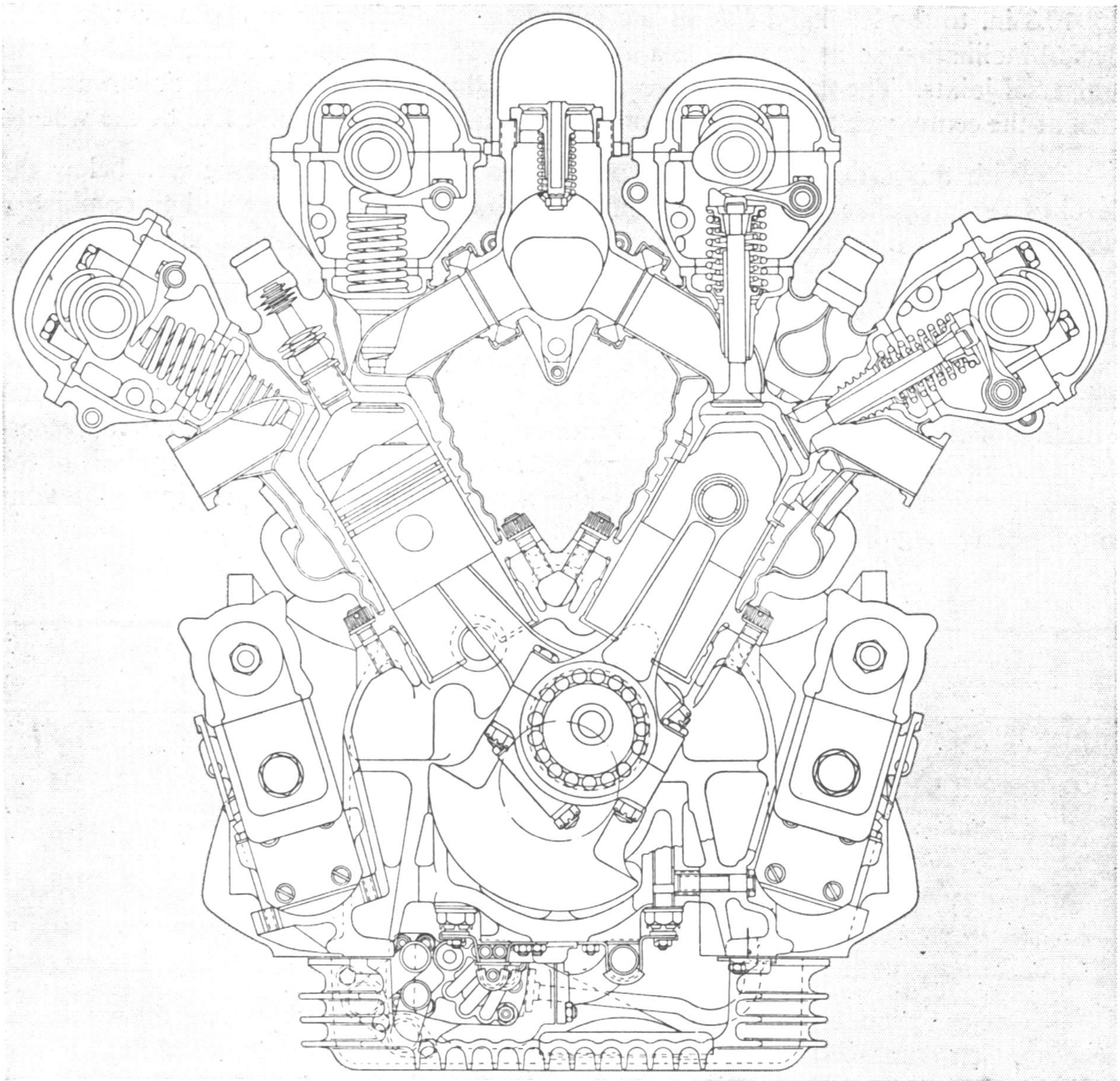
One can probably add 5 per cent to the above figures as representing the maximum speeds which were possible on any given ratio as the engine peaked at 7,800 r.p.m. and cases were known of 10,000 r.p.m. being realised in the lower ratios.

The reduced height of the engine was matched by a major change in the layout of the cooling services. On the type 154 the height of the radiator was reduced to 27 in. from the ground and the required total cooling area of 1.l sq. ft. was attained by increasing the width to 31 in.

On the W.163 this process was carried a stage further and the radiator core put forward 3½ in. and reduced in depth from 6 in. to 4 in. From 1937 onwards the coolant was 100 per cent ethylene glycol running in a closed system with blow-off valves set at 7½ lb. above atmospheric pressure. The engines ran at approximately 100 degrees C. and it is computed that the cooling drag was less than 10 per cent of the total. This covers both glycol and oil temperature reduction and a large section of the right-hand

part of the radiator core was devoted to oil cooling. A novel feature, present on the type M.163 only, was a fuel radiator mounted separately ahead of the main core.

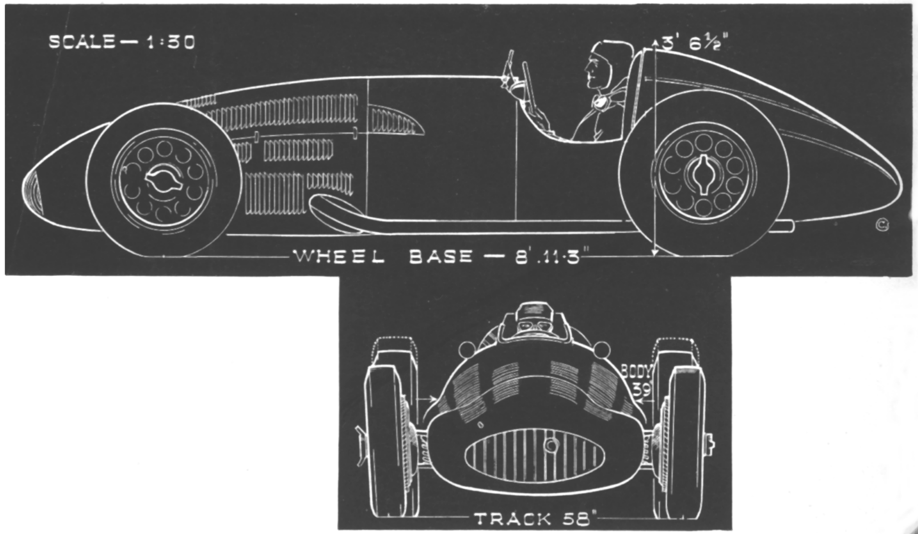
Throughout 1938 the cars were troubled with difficulty in starting after a pit stop due to vapour lock and boiling of the lighter fractions of the alcohol mixture



As a combination of high power output with compactness and low frontal area the 2.96-litre Mercedes-Benz V.12 represents the highest pinnacle of the designer's art. This quarter-scale cross-section shows the principal features of the construction.

(8.8 per cent acetone and 0.8 per cent sulphuric ether), one reason for this being the very high proportion of under-bonnet space occupied by the engine and consequently extremely rapid rise in under-bonnet temperature once the car was brought to rest.

When this design was introduced in 1938 (Ml54) a great deal of trouble was experienced with " frothing " and consequent loss of oil from the crankcase. This was undoubtedly caused by greater r.p.m., which led in turn to piston ring flutter and blow-by into the crankcase. This was cured relatively easily, but with the more complicated internal construction of the V12 engine, scavenging of the crankcase, and return



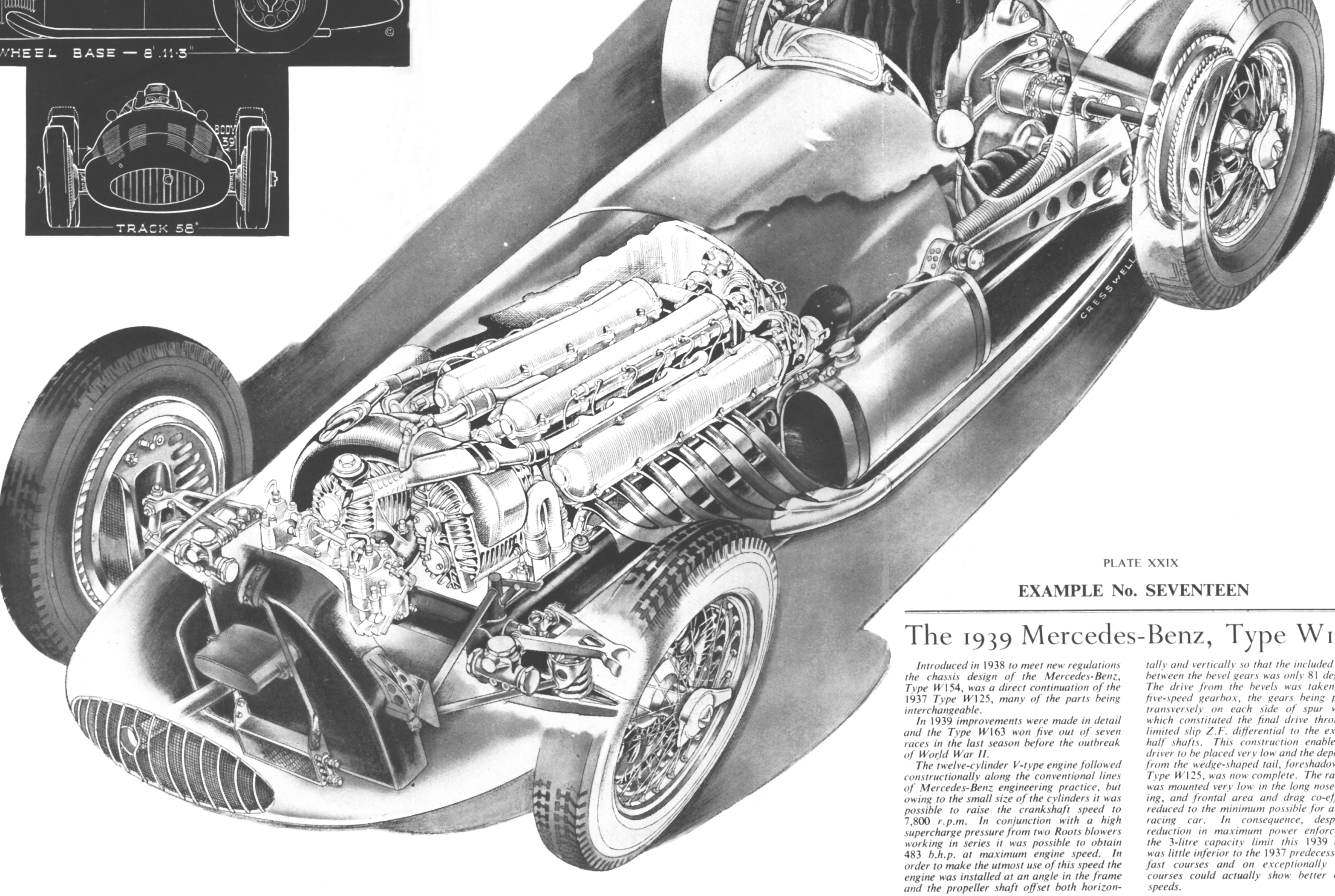


PLATE XXIX

EXAMPLE No. SEVENTEEN

The 1939 Mercedes-Benz, Type W163

Introduced in 1938 to meet new regulations the chassis design of the Mercedes-Benz, Type W154, was a direct continuation of the 1937 Type W125, many of the parts being interchangeable.

In 1939 improvements were made in detail and the Type W163 won five out of seven races in the last season before the outbreak of World War II.

The twelve-cylinder V-type engine followed constructionally along the conventional lines of Mercedes-Benz engineering practice, but owing to the small size of the cylinders it was possible to raise the crankshaft speed to 7,800 r.p.m. In conjunction with a high supercharge pressure from two Roots blowers working in series it was possible to obtain 483 b.h.p. at maximum engine speed. In order to make the utmost use of this speed the engine was installed at an angle in the frame and the propeller shaft offset both horizontally and vertically so that the included angle between the bevel gears was only 81 degrees. The drive from the bevels was taken to a five-speed gearbox, the gears being placed transversely on each side of spur wheels which constituted the final drive through a limited slip Z.F. differential to the exposed half shafts. This construction enabled the driver to be placed very low and the departure from the wedge-shaped tail, foreshadowed in Type W125, was now complete. The radiator was mounted very low in the long nose cowling, and frontal area and drag co-efficient reduced to the minimum possible for a road-racing car. In consequence, despite a reduction in maximum power enforced by the 3-litre capacity limit this 1939 design was little inferior to the 1937 predecessors on fast courses and on exceptionally twisty courses could actually show better circuit speeds.

of oil into the external tanks, presented many serious problems which persisted during the first half of the 1938 season. Detail changes brought relief, whilst the problem was entirely cured in the 1939 engines, which were equipped with no fewer than nine separate oil pumps, detail application being carried so far that even the supercharger gear casing had its own individual scavenger pump.

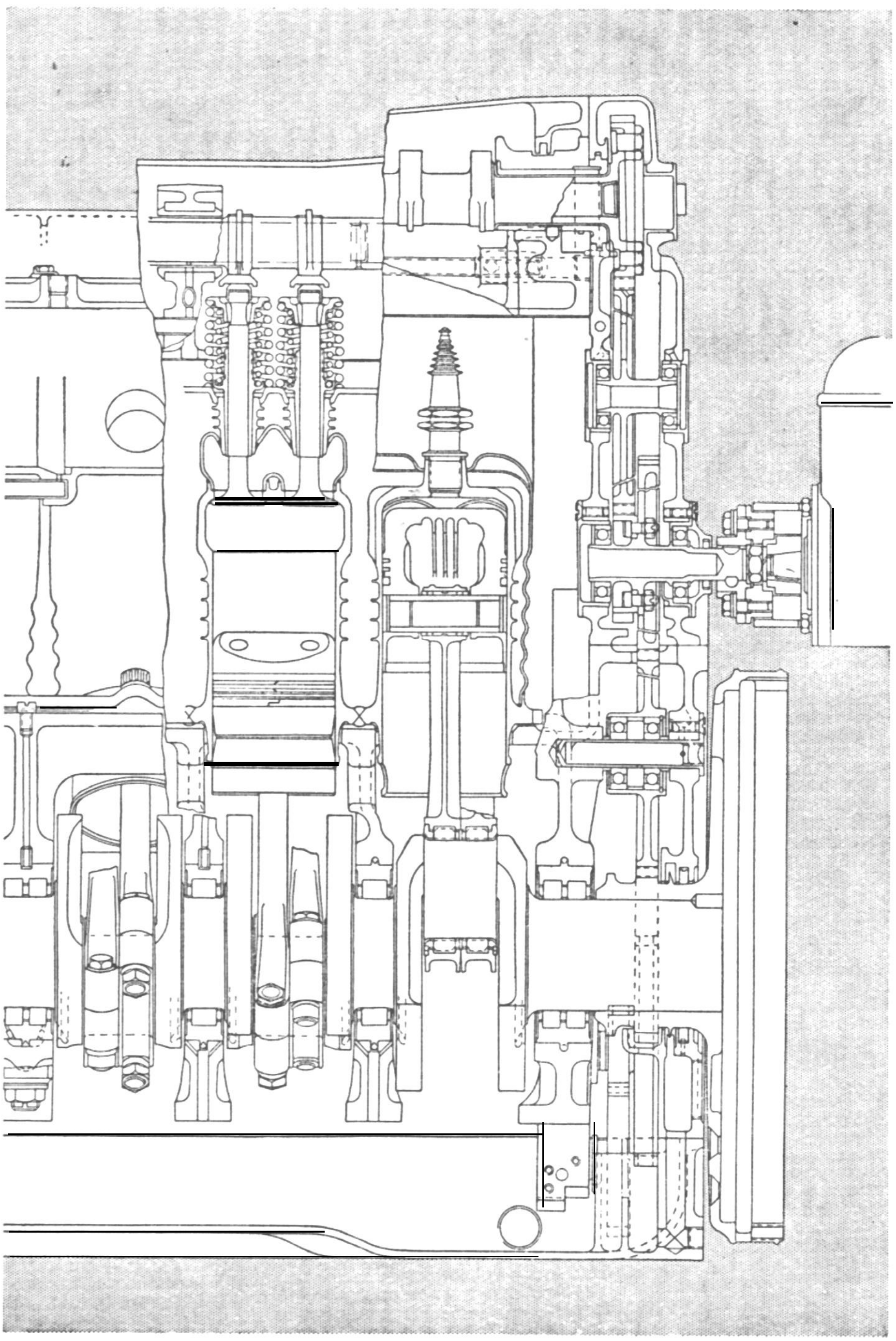
Reduced engine size and increased supercharged pressures resulted in very heavy specific road consumption, it being something under 3 m.p.g. In order, therefore, to traverse, say, 200 miles non-stop with a certain margin in hand a minimum capacity of, say, 70 gallons was required. In point of fact, on the type W.163 the tank capacity was 88 gallons, and in order to accommodate this it became absolutely essential to use more than the space available in the tail of the car which offered a maximum of 50 gallons. In fact, on these cars the tail tank carried 48 gallons, a further 40 gallons being contained in a large saddle tank which formed virtually the dash structure. In view of the disastrous results likely to result from a leak in a tank placed so close to the ignition apparatus and exhaust system it was three-point mounted in order to relieve it from strain due to flexing of the chassis. The tanks had a common filler orifice at the back. It will be observed that the weight of the car would vary by more than 5 cwt. as between the car leaving the starting line with the tank full and running nearly empty before the replenishment stop, this figure being over 20 per cent of the all-up weight. In consequence weight distribution was bound to vary and the 60 per cent carried on the rear wheels on the starting line would drop 52-53 per cent. To mitigate the consequences of this change in trend the driver was provided with a " ride control " whereby the damping of the rear shock absorbers could be varied as the level of the tanks fell.

A scale drawing illustrates the extremely compact engine installation, although the drawing, in fact, is an early project and does not represent either the body lines or radiator mounting which was finally used. In particular, on the 1939 car the radiator core was very closely cowled by the forward part of the bonnet, which projected well ahead of the leading edge of the front tyre. A ram effect was achieved in this way at high speeds, which would improve both cowling efficiency and give a slight boost on the air intake, which would be balanced by the small flexible pipes running to the sealed float chambers. The carburetter was of the Mercedes-Benz Schiebervergaser type. This consisted of a single casting embracing two jet and choke assemblies, two float chambers and accelerator pump. The horizontal choke assemblies were separated by a third passage containing a barrel-type throttle, which was opened from shut to fully open with the least fraction of an inch of movement on the accelerator pedal.

A jet 3 mm. diameter was then disclosed giving a substantial enrichment of the alcohol mixture, which was a Standard Oil Co.'s W.W., as used on the 1937 vehicles.

On the 3-litre engines two superchargers were mounted horizontally and driven by spur wheels from the nose of the crankshaft. The supercharge drive was through a spring drive and a friction clutch, having thirteen plates, through which the mass of the rotors acted as a damper to the crankshaft. The drive location of the blowers were identical as between the 1938 type M.154 and the 1939 type M. 163, but whereas the former had two equal-sized blowers working in parallel, the latter had two unequal-sized blowers working in series. On the 1938 car the rotor dimensions were 106 mm. diameter by 150 mm. long, each having a theoretical delivery of 1.07 litres and being

driven at 2.78 times the engine speed. Thus, the total delivery of both blowers was 5.65 litres per crankshaft revolution, or 3.8 times the engine swept volume. With a volumetric efficiency of 60 per cent, this is the equivalent to a boost pressure of *circa* 18 lb. sq. in., which is very much higher than is theoretically desirable for a Roots-type blower, which has no internal pre-compression. The power absorbed in the blowers was, in fact, over 150 b.h.p., and in 1939 a development programme was initiated to reduce this loss. Experiments with Vane-type superchargers with an internal compression ratio proved that developments were required to achieve mechanical reliability, and this led to the use of a pair of Roots blowers working in two stages. The first stage comprised a blower with rotors 125 mm. diameter and 220 mm. long with a capacity



This drawing reveals the widespread use of roller bearings on the Type M.163 engine, the use of split housings, and a one-piece crankshaft, being a well-tried feature of these cars. This drawing also portrays the welded-up construction used for the cylinders.

of 1.73 litres. This was driven at 2.55 times engine speed, at which ratio the delivery was equal to 18 lb. boost at a volumetric efficiency of 75 per cent. The intermediate-stage blower was driven at the same speed and had rotors 125 x 125 mm., the capacity thus being approximately 0.55 that of the first stage. By this means the pressure rise across each blower was kept below 15 lb. On all Mercedes-Benz engines the top speed of the supercharger rotors was limited to approximately 400 ft. per second, and this factor may be considered to set a limit on the blower r.p.m. There are obviously considerable advantages to be derived from gearing up of the blowers, both in respect of obtaining maximum output for a given size and weight, and also in keeping a flat delivery curve and avoiding a fall in boost pressure leading to reduced b.m.e.p. in the lower part of the speed range curve. On the Ml54 and Ml63 the b.m.e.p. curve was, in fact, almost flat from 3,000 up to 5,000 r.p.m., but it must be admitted that on these high speed V12 engines carburation defects gave irregular response to wide throttle opening below 4,000 r.p.m. The normal operating speeds for these engines lay, therefore, between 4,500 and 7,500 r.p.m.

Conjointly with the change in supercharging arrangements valve timing was modified, the differences between 1938 and 1939 being as follows :

VALVE TIMING ON 3-LITRE MERCEDES-BENZ CARS

	Type 154	*Type* 163
Inlet open	28 degrees b.t.d.c.	40 degrees b.t.d.c.
Inlet closes	58 degrees a.b.d.c.	67 degrees a.b.d.c.
Exhaust opens	53 degrees b.b.d.c.	47 degrees b.b.d.c.
Exhaust closes	33 degrees a.t.d.c.	31 degrees a.t.d.c.

Together these changes resulted in a marked increase in engine output which is disclosed in some curves. The percentage gains as between the engine as originally tested and as finally run in 1939 were as follows :

PER CENT GAIN IN ENGINE OUTPUT OF 1939 M.163 OVER 1938 TYPE M.154

R.P.M.	*Per Cent Gained*
3,000	134
4,000	10
5,000	9
6,000	9½
7,000	14.35
7,500	12

During the 1939 racing season it was rumoured that the type M.163 was using direct fuel injection into the cylinders. A design was, in fact, prepared as early as 1937,

using two of the well-known Bosch fuel-pump injectors into the inlet ports, but owing to disappointing results on a single-cylinder test rig no full-scale engine trials were carried out. The tests showed that with fuel injection, 146.3 h.p. per litre was realised at a piston speed of 3,450 f.p.m., whereas with normal fuel-air aspiration through a blower 166.5 h.p. per litre was obtained at 2,600 f.p.m.

The general structure of the 1938 and 1939 engines was identical and showed no great departure from previous Mercedes-Benz practice, except that, in order to raise the piston area to a maximum in relation to cylinder volume, twelve cylinders in V formation were used. The company had prior experience of this type on record breaking engines of 5.57-litre capacity built in 1936, but the 3-litre engines were, of course, an entirely new design. They weighed substantially more than the type M. 125 eight-cylinder of nearly twice the cylinder capacity, the exact figures being 5.66-litre type M.125, 486 lb. ; twelve-cylinder 3-litre type M.154, 558 lb. ; twelve-cylinder 3-litre type M. 163, 603 lb.

The imposition of a capacity limit, it will be noted, increased the weight of the engine from 0.7 lb. per b.h.p. to 1.25 lb. per b.h.p., but with the change from a maximum to a minimum weight limit this was not a decisive factor. The general arrangement drawing shows how the cylinders were built up in blocks of three, the general construction being exactly similar to the previous models, including a deep spigot into the crankcase.

The latter followed the lines of the last of the eight-cylinder type, being split very much below the centre line and having tie-bolts threaded into the main-bearing caps in order to assist lateral rigidity of the crankcase. The six-row crank ran in seven-roller main bearings, the journals being 60 mm. diameter and the crankpins 54 mm. The cylinder centres were offset by 18 mm. and the connecting rods were mounted side by side on the pins, the big ends being split, as were the cages for the rollers. The two halves were connected by a pair of big-end bolts for each rod, the joint between them being serrated so as to provide for maximum accuracy in assembly and the reduction of distortion when pulling up the big-end bolts, a point of particular importance when the rollers were running direct in hardened tracks in the eye of the big end.

The main bearings used 10 mm. by 14 mm. rollers, the big ends being smaller, viz., 8 mm. by 12 mm. At the very high rotational speeds of which these engines were capable (up to 9,000 r.p.m.), fretting of the roller-bearing cages and break-up of the big ends was a not uncommon trouble, and the design department had in mind a radical change in policy embracing the use of one-piece big ends and cages, with built-up crankshaft on the Hirth system.

The drawing shows the very careful design of the rod, and the diameter of the gudgeon pin (20 mm. or 30 per cent of the cylinder diameter) shows a definite increase as compared with the earlier cars running on a much lower boost pressure.

The rod measured 151 mm. between centres, that is stroke x 2.15. It was thus a good deal longer in proportion than on the eight-cylinder engine, in which the connecting rod measured 168 mm. between centres or stroke x 1.62.

The steeply domed light-alloy pistons were constructed by Mahle and the very low mounting of the piston rings in relation to the crown was a point of particular interest and shows that the designers had appreciated the very large gas loading which can be imposed with comparatively high supercharged pressures.

The total mass of the reciprocating parts was approximately 2.8 lb., and although the connecting rod is obviously designed for minimum weight, it is equally obvious that in the piston considerations of rigidity and heat dissipation have been regarded as being of primary importance.

The lubrication of the system consists of jets feeding the main bearings at low pressure with further passages drilled on a tangent to oil-collector rings machined in cheeks of the crank webs. At this point centrifugal force passes the oil through the hollow crankpin to the big ends, gudgeon pins being lubricated solely by splash.

The dry sump system was employed, a large oil tank being mounted on the near side of the car.

In the early stages of development serious trouble was experienced with oil being blown out of the crankcase through the breather pipes. High output V-type engines are liable to this trouble, due to the exceedingly small cubic content of the crankcase in relation to that of the cylinders.

There were separate systems covering the crankshaft, camshafts and supercharger drive, and very great care was taken throughout the design to meter the oil through the crankshaft so that each bearing received the same quantity. Equal attention to detail can be observed in the fine-gauze filters which are embodied in the camshaft delivery system.

The intermediate timing wheels provided a drive for the two Bosch magnetos, which were mounted on an overhanging bracket attached to the rear of the timing cover. The final gears were bolted to the camshafts, which were supported in plain bearings and opened the valve through trailing fingers. The valve lift was approximately 8 mm., the valves being 30 mm. diameter inclined at an included angle of 60 degrees. With four valves per cylinder, the total inlet-valve area thus came to 26.2 sq. in., the power developed being 18.6 b.h.p. per sq. in. of valve area. The sparking plug was mounted directly upon the apex of the pent-roof-type cylinder head, and 18 mm. Bosch plugs were used. These were generally type No. 490.

The forward end of the engine carried gears giving a right-angle drive to the fuel pump on the near side of the coolant pump on the off side of the engine. The former was a fully mechanical aviation type and the latter of the conventional centrifugal form, supplying Glycol to external manifolds and to the base of the steel cylinder blocks. Individual coolant off-take pipes were mounted on the top of the cylinder heads, the radiator header tank being just high enough to avoid the necessity for any separate tank above the level of the head.

Despite every technical endeavour the 1939 3-litre cars were not able to match the 1937 models in power per sq. ft. or per laden ton. They were thus inevitably slower in respect of acceleration, but owing to the improved form of the body there appeared to be little difference in the maximum speeds actually realised on the road. The earlier cars, moreover, had really too much surplus power for the mental comfort of their drivers, and the 1939 models were certainly superior in the important matters of stability and braking. As a consequence the 1939 Mercedes-Benz cars may claim to have been the fastest cars in the world on a road circuit.

DETAILS OF CAR

MAKE.-Mercedes-Benz
TYPE.-W. 163
YEAR OF CONSTRUCTION.-1939
YEAR RACED.-1939
DESIGNER.-Oberings Wagner and Hess under Dir. Max Sailer
WHEELBASE.-8 ft. 11.3 in.
TRACK FRONT.-4 ft. 10 in.
TRACK REAR.-4 ft. 7 in.
HEIGHT TO SCUTTLE.-34½ in.
HEIGHT TO DRIVER'S HEAD.-42½ in.
FRONTAL AREA.-12.5 sq. ft.
UNLADEN WEIGHT.-17.6 cwt.
ALL-UP STARTING LINE WEIGHT.-24.1 cwt.
MAXIMUM SPEED.-195 m.p.h. at 7,800 r.p.m.
SPEED ON GEARS.-According to circuit. For German G.P. Nürburg Ring.-195 m.p.h. on Fifth ; 157 m.p.h. on Fourth ; 133 m.p.h. on Third ; 109 m.p.h. on Second ; 60 m.p.h. on First at 7,800 r.p.m.
H.P. PER SQ. FT.-39
H.P. PER TON UNLADEN.-550
H.P. PER TON ALL-UP.-405
BORE.-67 mm.
STROKE.-70 mm.
S./B. RATIO.-1.045 : 1
NO. OF CYLINDERS.-Twelve
CAPACITY.-2,962 c.c.
PISTON AREA.-65.5 sq. in.
B.H.P.-483 at 7,800 r.p.m.
H.P. PER SQ. IN.-7.95
B.M.E.P.-270 lb. sq. in.
PISTON SPEED FT. PER MIN.-3,600
CYLINDER HEAD.-Integral steel
VALVES No.-Four per cylinder
VALVES ANGLE.-60 degrees
VALVES AREA-Inlet 26.8 sq. in.
VALVES AREA EXHAUST.-26.7 sq. in.
CYLINDER BLOCK.-Forged steel barrels welded together into four sets of three with sheet water jackets and mounted in V formation with two sets per bank at an included angle of 60 degrees
FUEL.-86 per cent Methyl Alcohol mixture
CARBURETTERS.-One Mercedes-Benz with triple choke tube, and twin float chamber
SUPERCHARGERS.-Two Roots in series giving two-stage boost.
SUPERCHARGE PRESSURE.-26.5 lb. boost (2.86 ata.)
IGNITION.-Two Bosch magnetos
PLUGS No.-Twelve
PLUGS LOCATION.-Centre of head
CRANKCASE.-Two-piece light alloy split below centre of main bearings.
CRANKSHAFT.-One-piece counterbalanced
MAIN BEARING No.-Seven
MAIN BEARING TYPE.-Roller
BIG END TYPE.-Roller in split housing
LUBRICATION.-Dry sump
CAMSHAFT No.-Two per bank
CAMSHAFT LOCATION.-In head
CAMSHAFT DRIVE.-Train of gears
CAMSHAFT DRIVE LOCATION.-Rear of crank
CLUTCH.-Single plate
GEARBOX LOCATION.-In unit with bevel box
GEAR RATIOS.-Varied with circuit. For German G.P. 4.0, 4.97, 5.8, 7.2, 10.6:1
TRANSMISSION.-Open propeller shaft inclined downwards to bring bevels 11.2 in. below hub centre line and inclined sideways to end transmission line 10.8 in. offset to nearside of car. All indirect gearbox with shafts mounted transversely driving exposed half-shafts with double universal joints with spur wheels and Z.F. differential
FRAME.-Oval tube
FRONT SUSPENSION-Independent to each wheel with wishbones and open coil springs
REAR SUSPENSION.-De Dion type with torsion bar springs
SHOCK ABSORBER TYPE.-Hydraulic
BRAKE SYSTEM.-Lockheed hydraulic
BRAKE DRUM DIAMETER.-16½ in. internal
BRAKE DRUM WIDTH.-3 in.
SQ. IN. PER TON LADEN.-510 sq. in.
STEERING.-Worm and nut, 2¼ turns lock to lock
WHEELS TYPE.-Rudge
TYRES FRONT.-525 by 17 Continental
TYRES REAR.-7 by 19 Continental

RACING RECORD MERCEDES-BENZ TYPE W.163

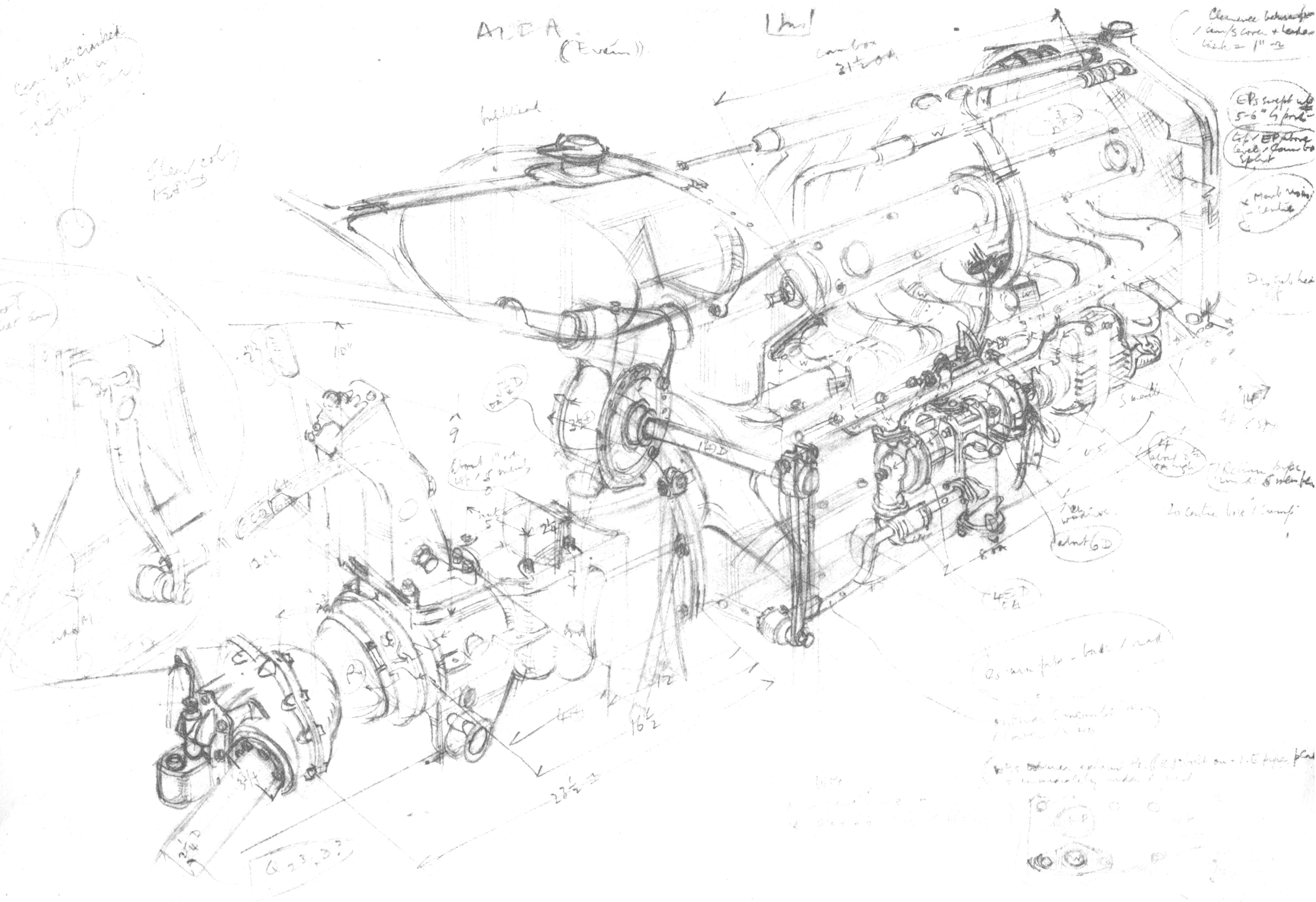
Date	*Event*	*Course*	*Average Speed*	*Lap Speed*
2/4/39	Pau Grand Prix . .	Pau	56.09 m.p.h.	57.83 m.p.h.
21/5/39	Eifel Races	Nürburg	84.14 m.p.h.	86 m.p.h.
26/6/39	Belgian Grand Prix . .	Spa	94.39 m.p.h.	109.12 m.p.h.
9/7/39	French Grand Prix . .	Rheims	Non-finisher	117.5 m.p.h.
23/7/39	German Grand Prix . .	Nürburg	75.12 m.p.h.	87.5 (P) m.p.h.
20/8/39	Swiss Grand Prix . .	Berne	96.02 m.p.h.	106.23 (P) m.p.h.
3/9/39	Yugoslav Grand Prix . .	Belgrade	81.03 m.p.h. (2nd)	83.9 (P) m.p.h.

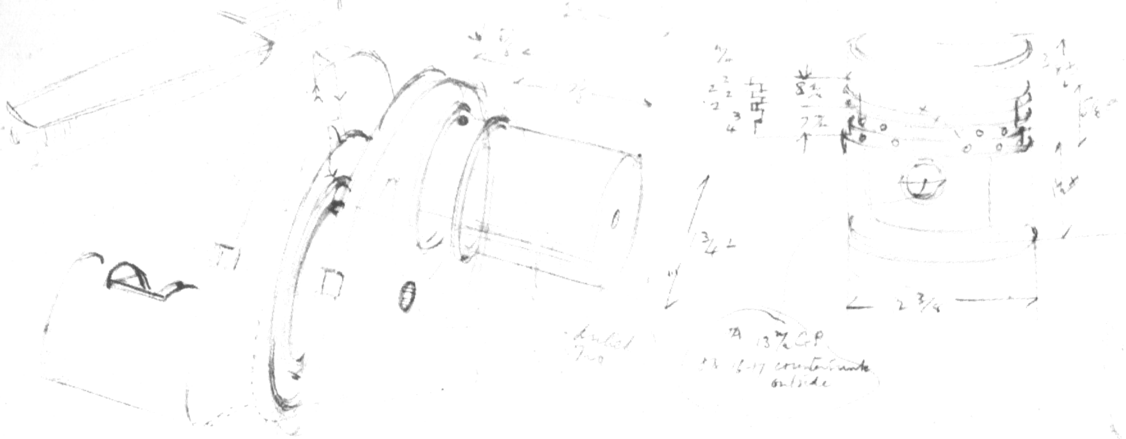
PORTFOLIO OF SKETCHES BY L. C. CRESSWELL

This portfolio of twelve original sketches by the artist who has illustrated this book is included in compliment to his skill.

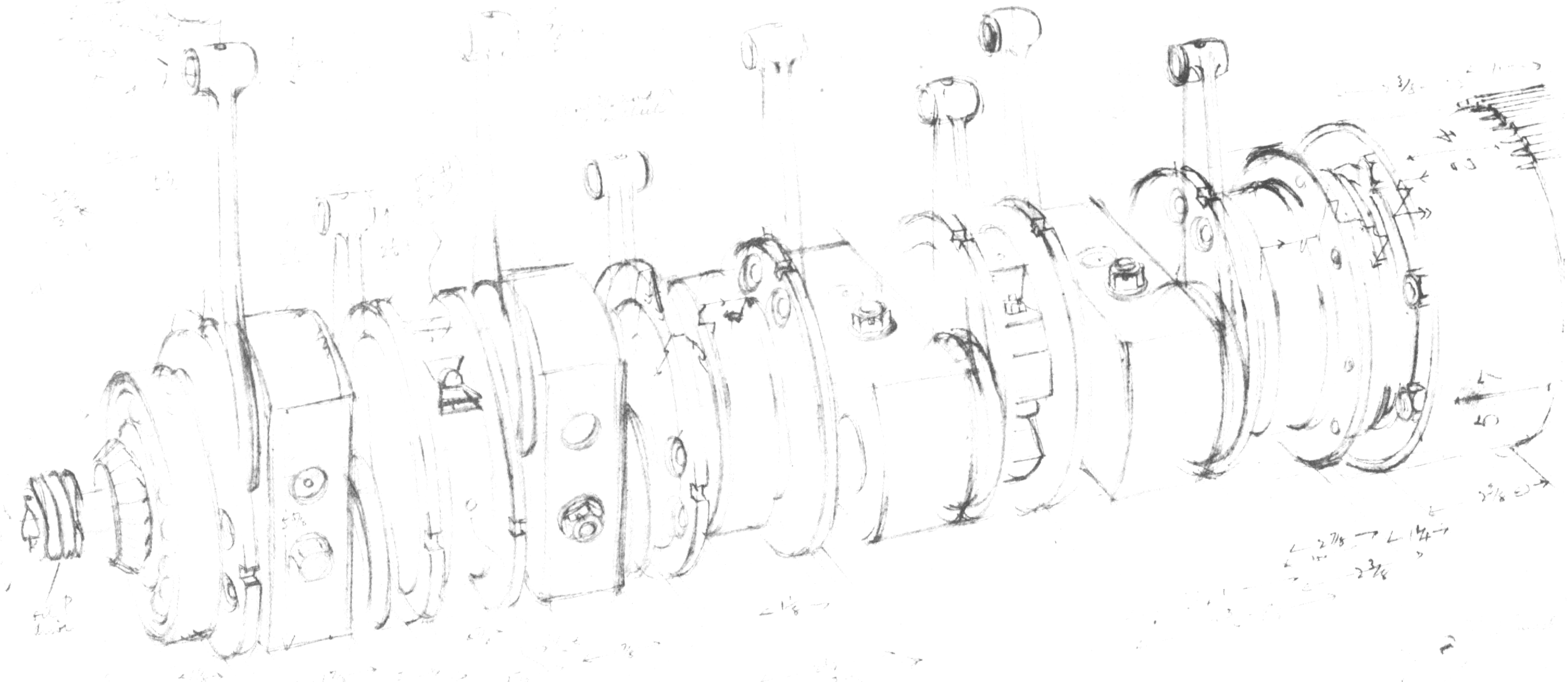
These sketches show the nature of his original "note-taking" which is done by the artist from the actual vehicle, and it is from these that he builds up the magnificent tone and line drawings which are included in this volume in the form of double page plates in Part II.

It will be of interest to note that all the illustrations in this book are the product of some 5000 hours work on the part of the artist, and it cannot be denied that he brings a refreshing touch to mechanical drawings which combine the meticulous accuracy of the drawing board with the essential character of the vehicle which is his subject.

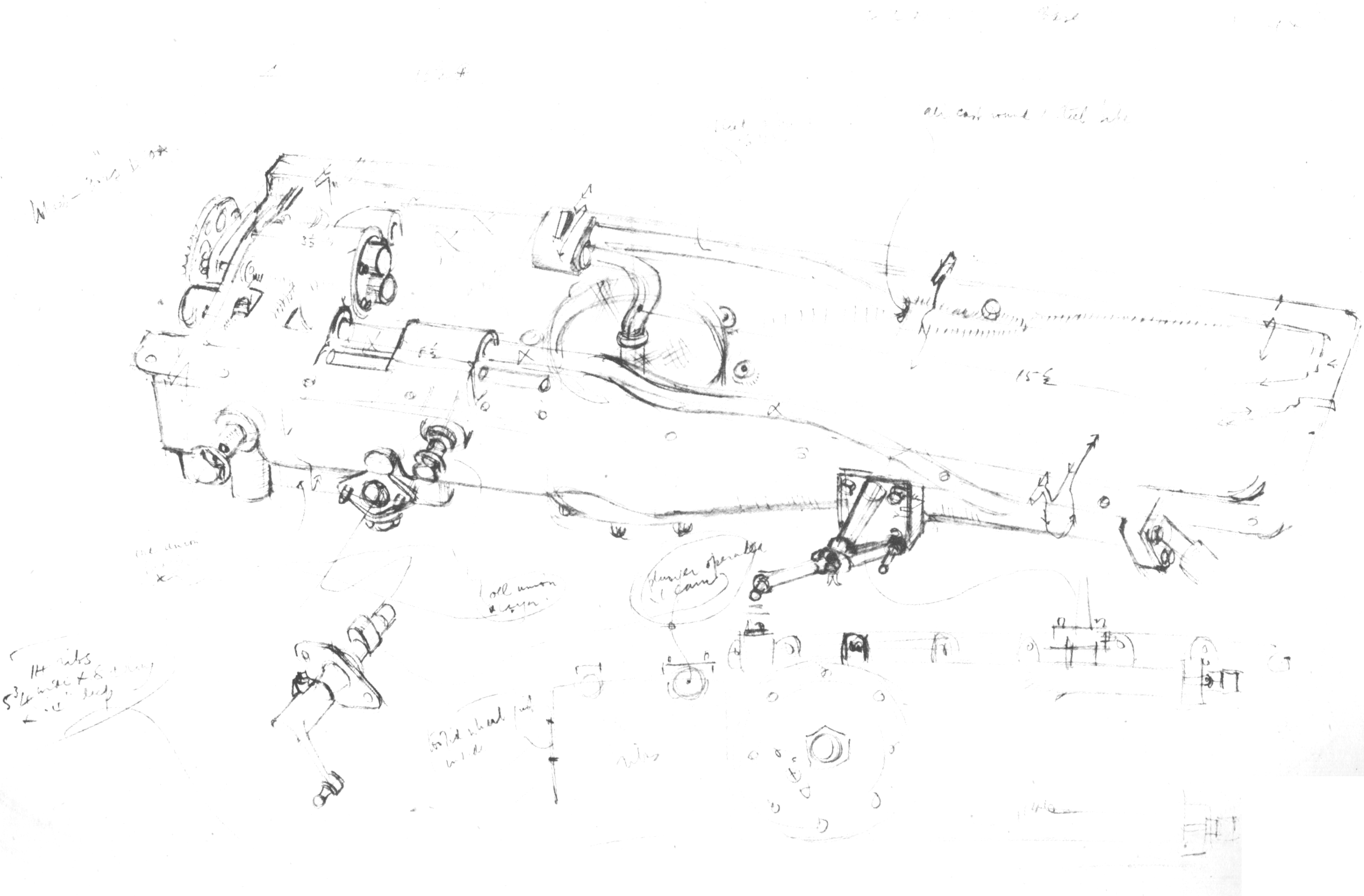




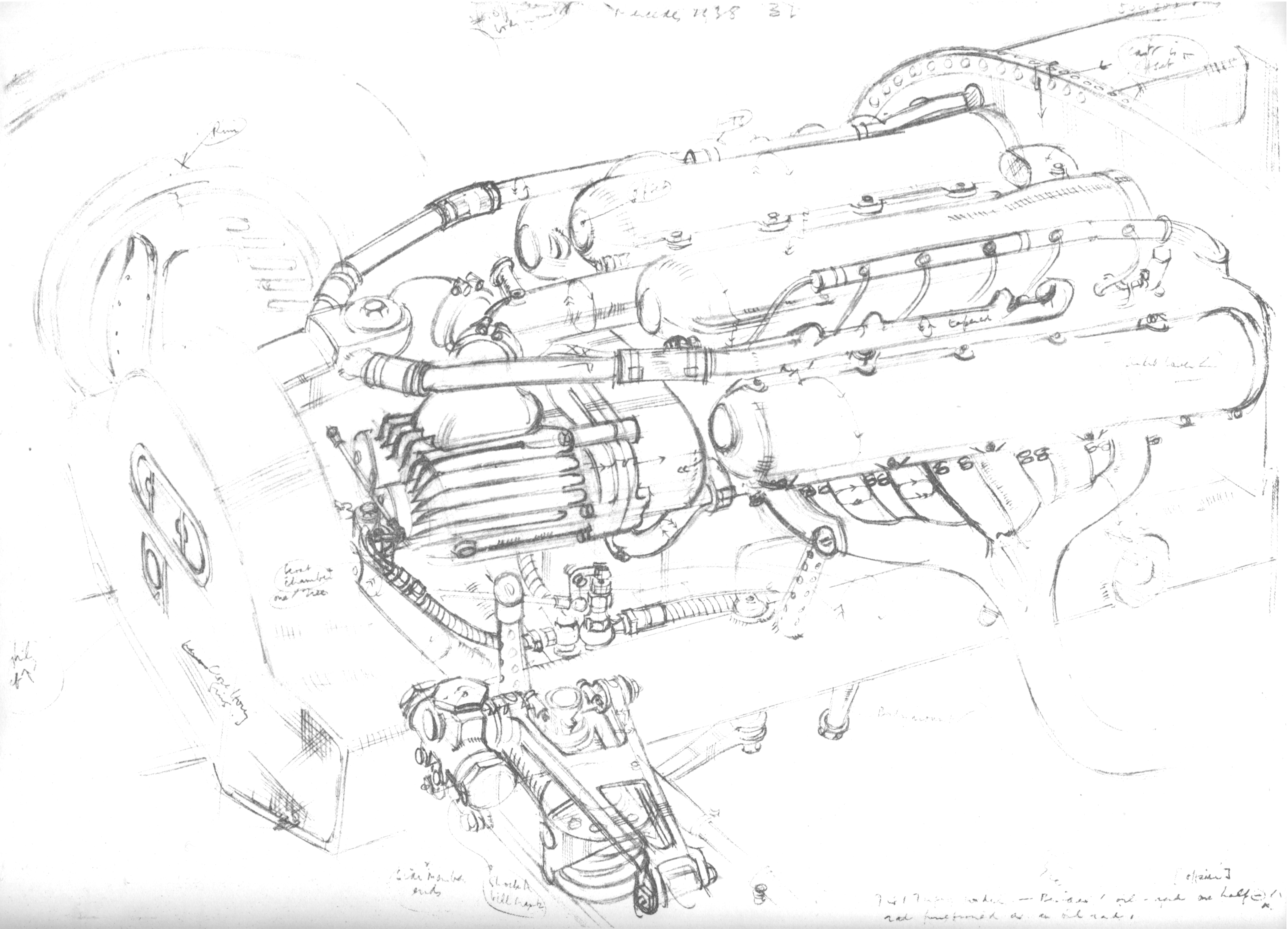
$2\frac{3}{4}$
13% CP
outside



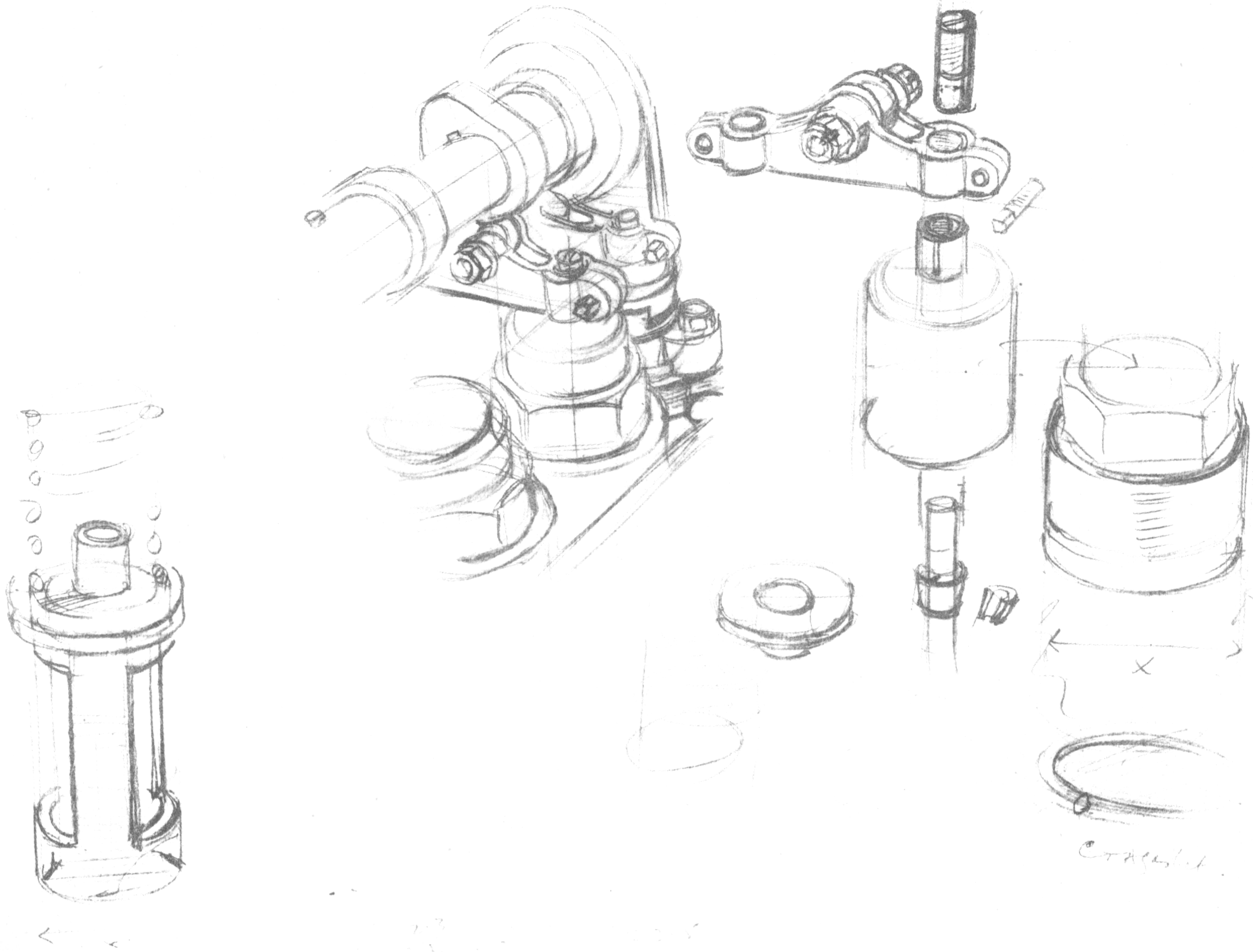
$2\frac{7}{8}$
$1\frac{1}{4}$
$2\frac{3}{8}$

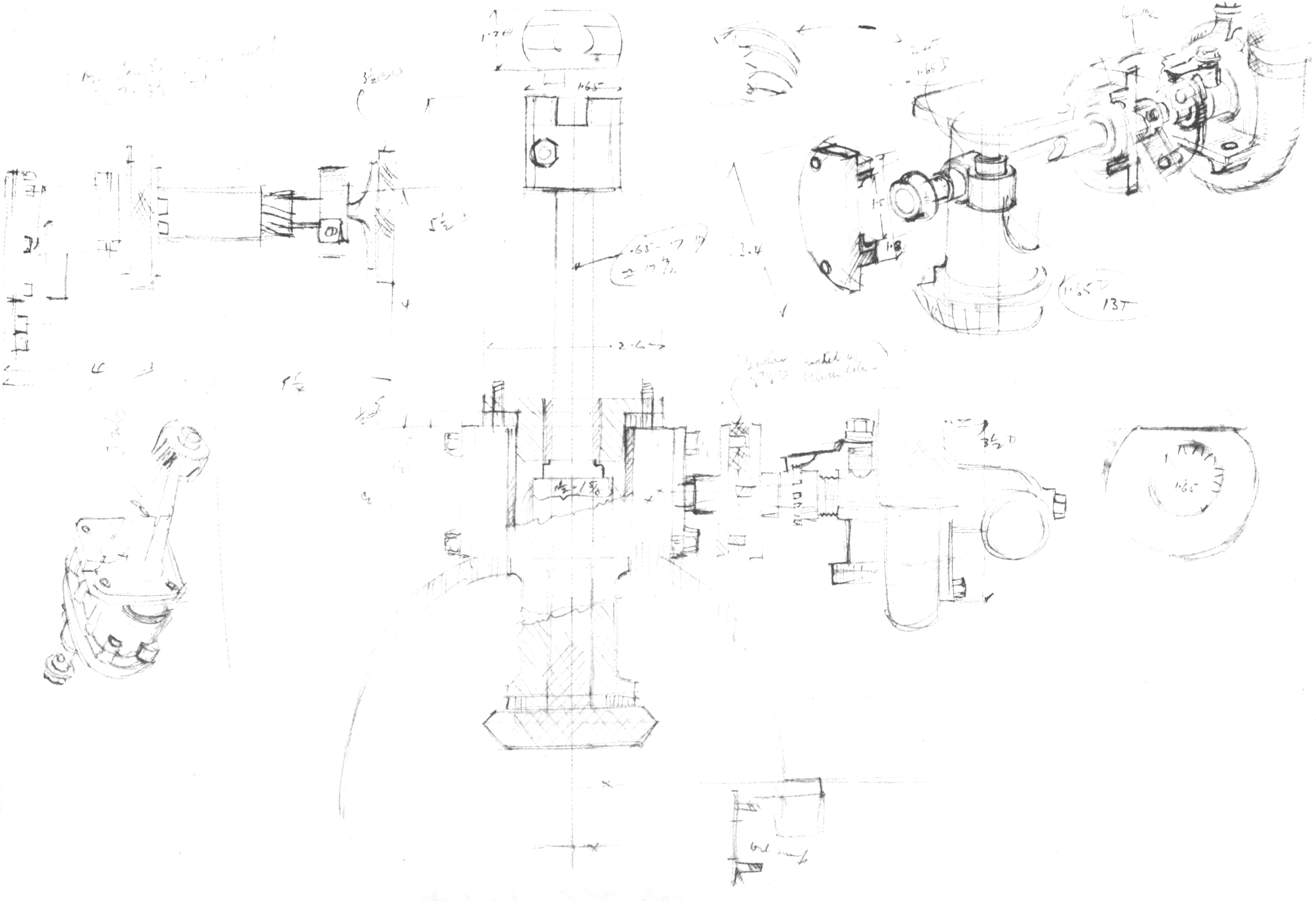


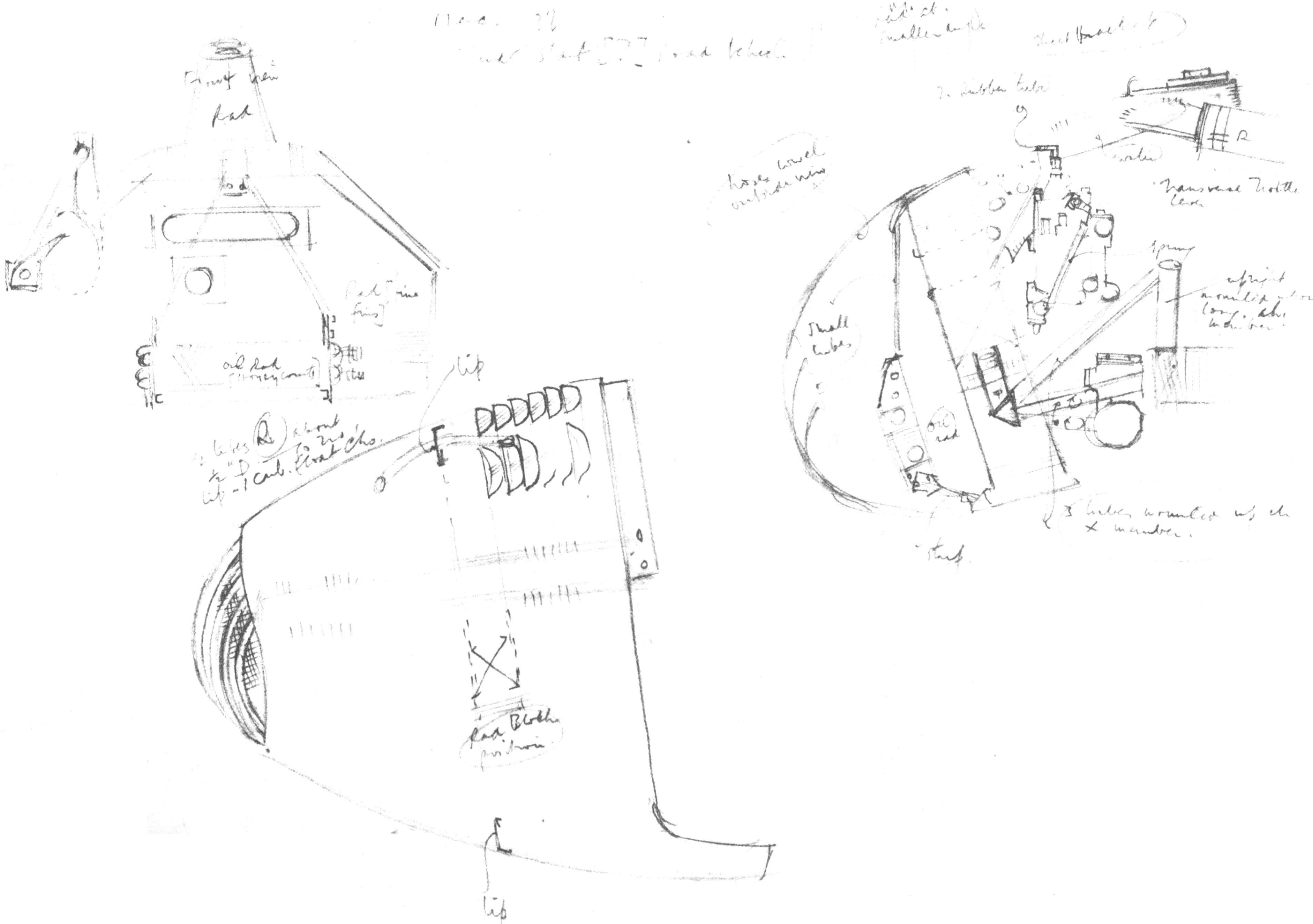
plunger operating
(cam)


Rim
tapered

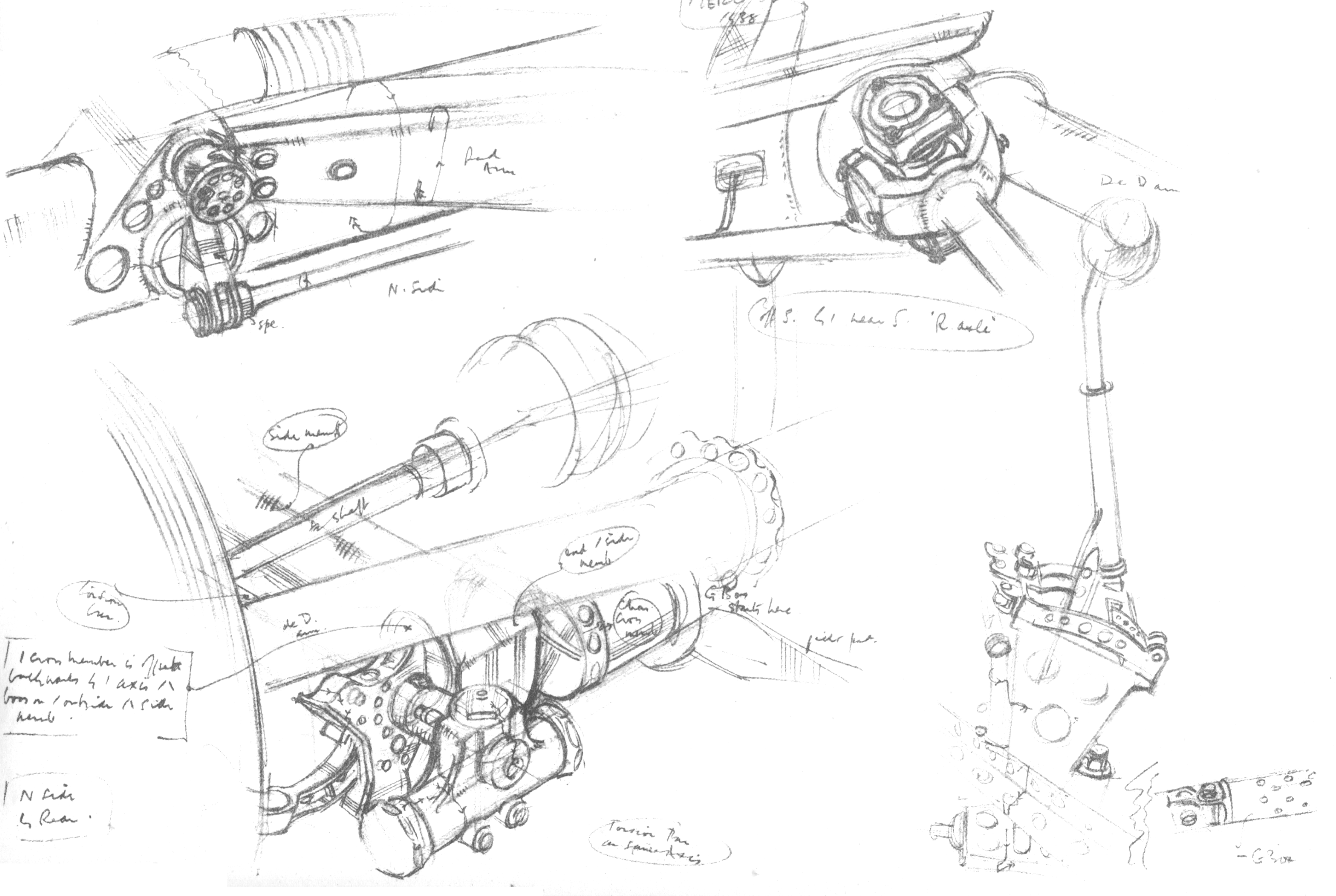
Lit.

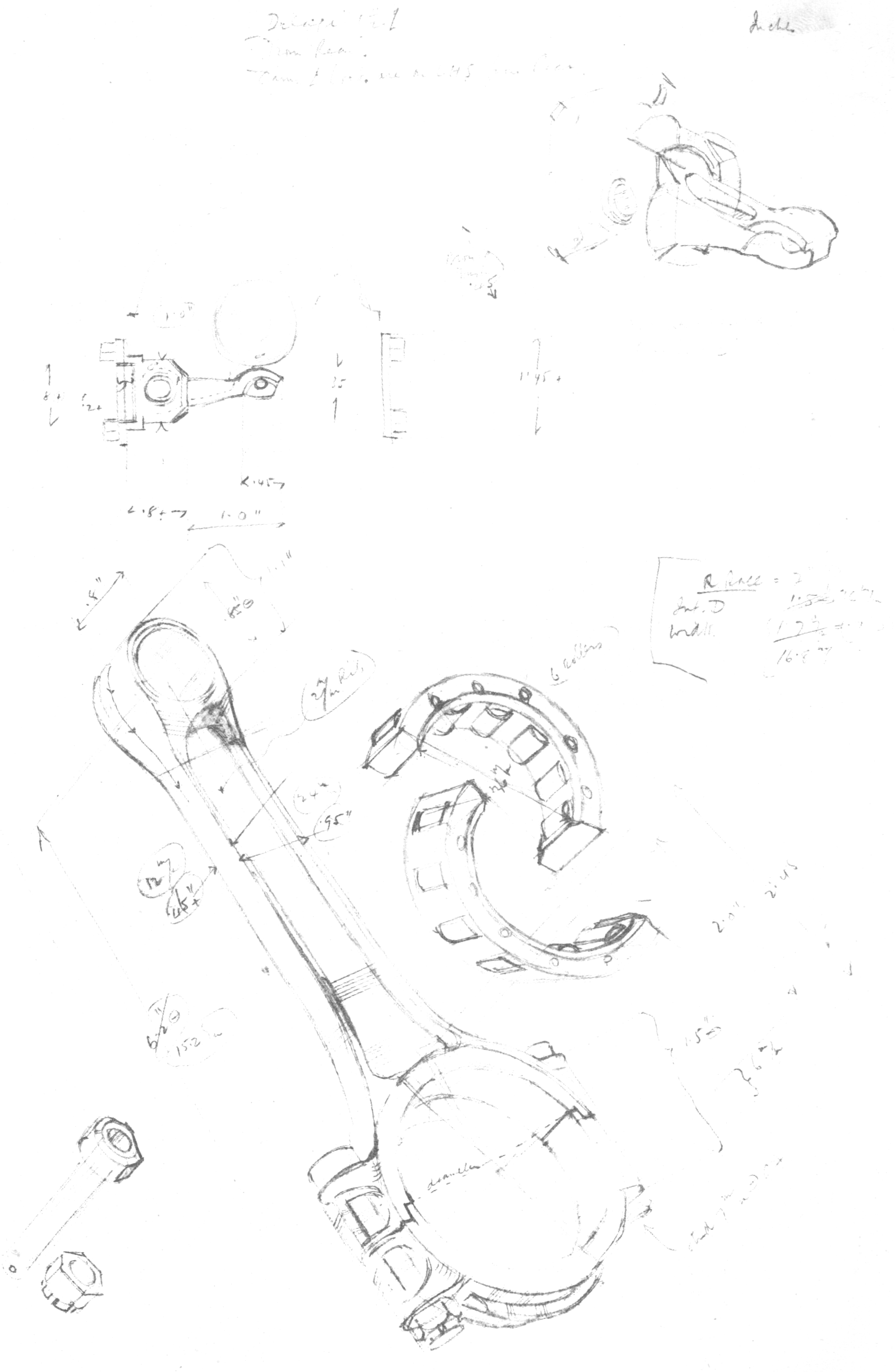


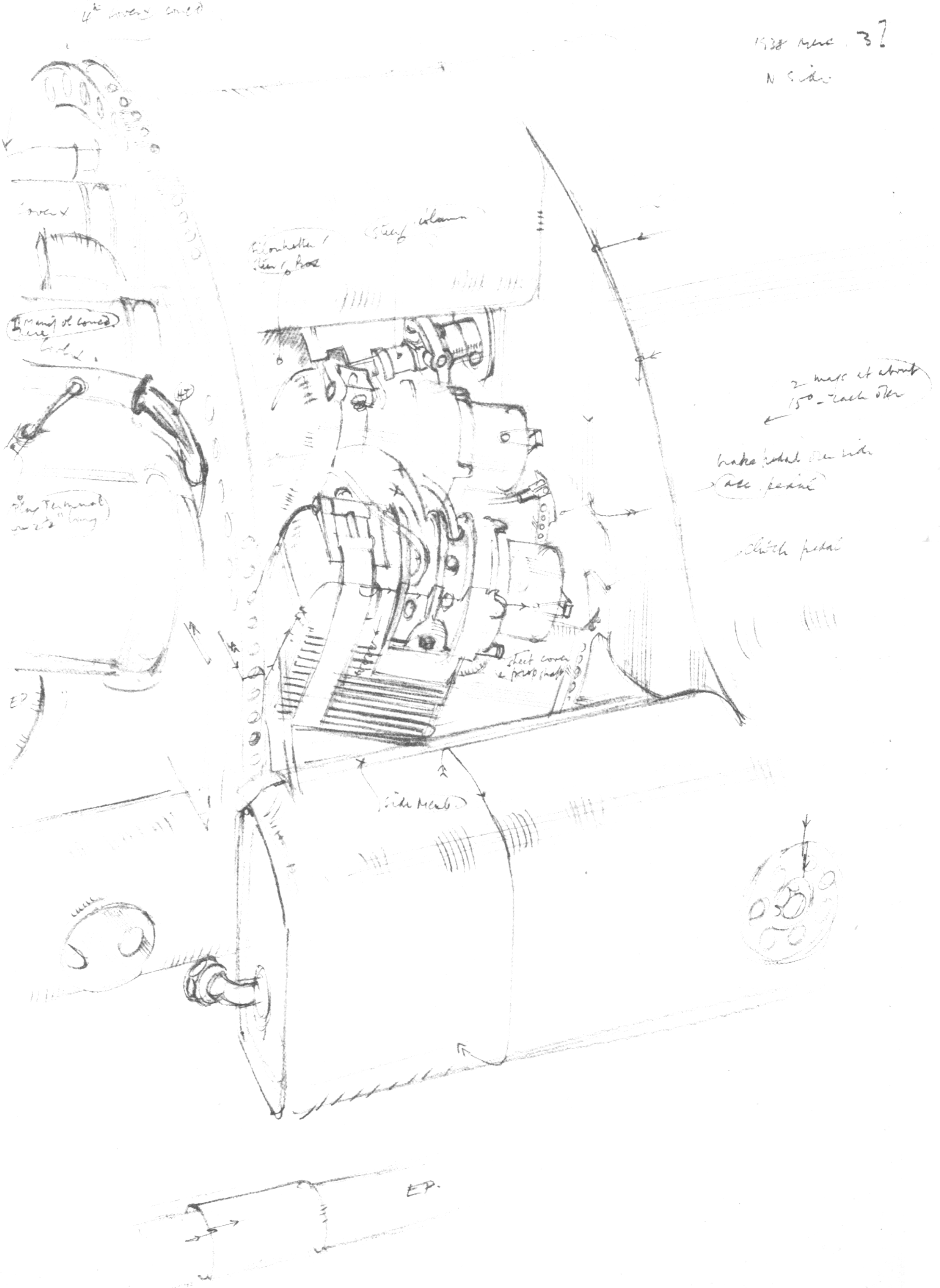


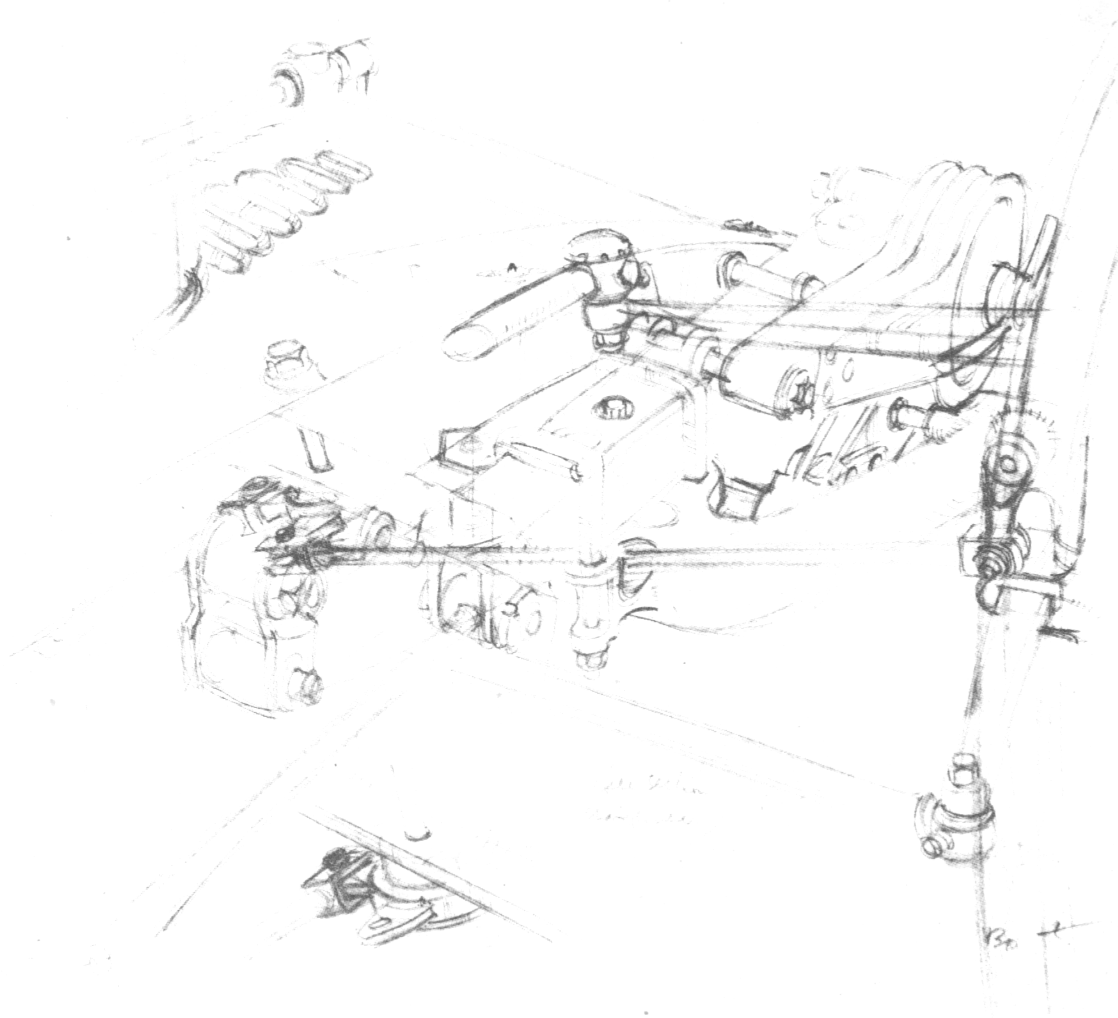


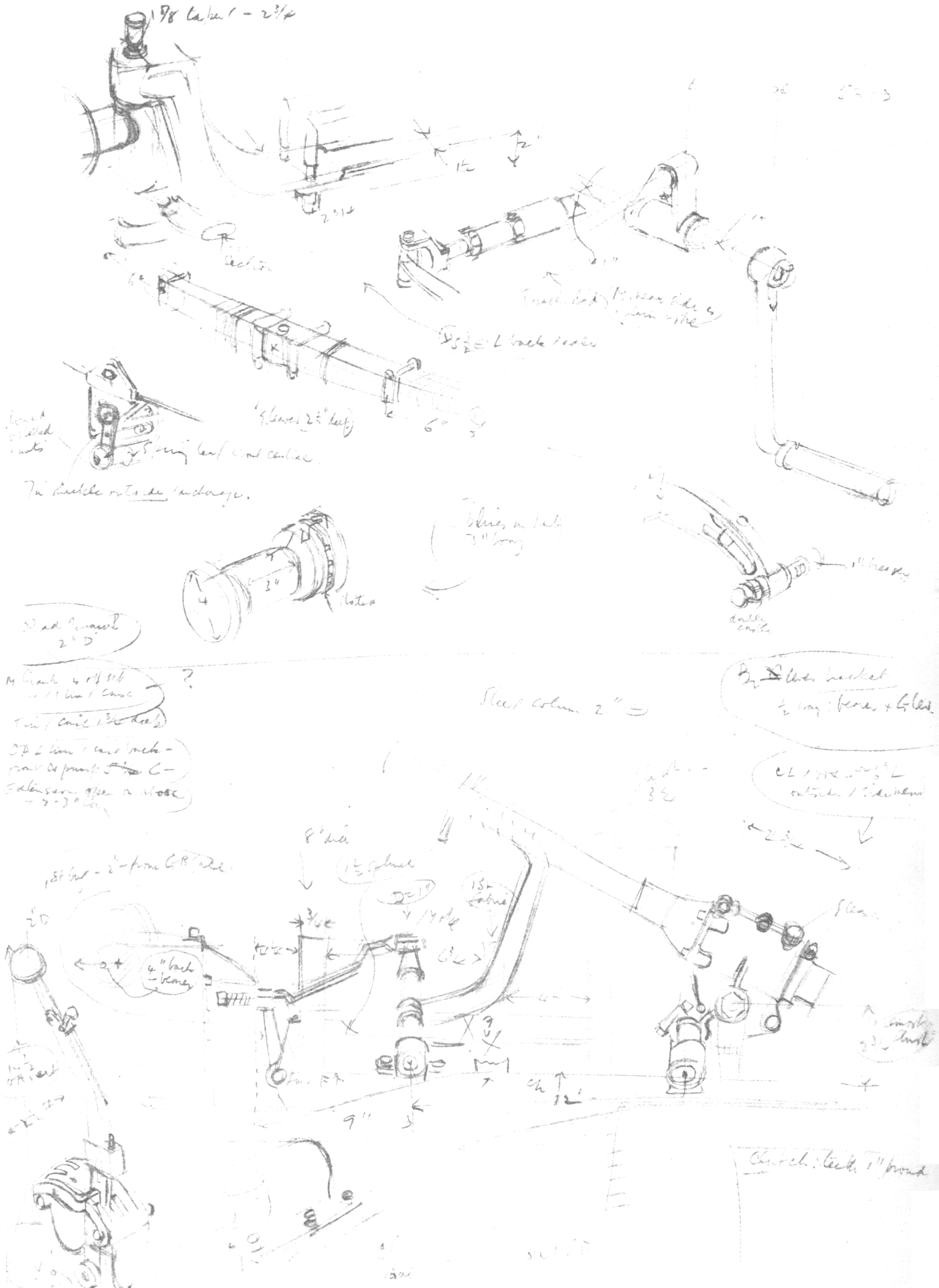
Front view
lip
Small tubes
Transverse Throttle lever
spring
Oil rad
lip


N. Side
De Dion
shaft
G Box starts here
N Side of Rear.
G Box


1.0"
1.45
1.0"
6 rollers
Int. D
Width
.95"
diameter


1938 Merc
N Side
Steering column
brake pedal other side
clutch pedal
sheet cover & prop shaft
side members
EP
EP.




Track Rod
6"
3"
Tie shackle outside anchorage.
8" dia
2"D
9"
12"
double cable

APPENDIX A
RESULTS OF THE 200 MOST IMPORTANT RACES 1906-1939

Date	*Course*	*Driver*	*Car*	*Index No.*	*Winning Speed m.p.h.*	*Lap Speed (Rec'd*)*
AMERICAN GRAND PRIX						
30/11/11	Savannah	D. Bruce Brown	Fiat	110	74.75	—
ARDENNES PRIZE						
13/8/06	Ardennes Circuit	L. Duray	De Dietrich	102	65.8†	—
,,	,,	L. Wagner	Darracq	103	—	70*
25/7/07	,,	J. T. C. Moore Brabazon	Minerva	106	59.5	—
,,	,,	A. Lee Guinness	Minerva	106	—	67
,,	,, (G.P. Class)	Baron de Caters	Mercedes	107	57.3	—
,,	,, (G.P. Class)	C. Jenatzy	Mercedes	107	—	66.6
ASTOR CUP						
30/9/16	Sheepshead Bay Track	J. Aitken	Peugeot	116	104.8	—
AVUSRENNEN						
2/8/31	A.V.U.S.	R. Caracciola	Mercedes-Benz	140	115.39	121.65*
22/5/32	,,	M. von Brauchitsch	Mercedes-Benz	140	120.07	—
,,	,,	R. Dreyfus	Maserati	147	—	130.39*
21/5/33	,,	A. Varzi	Bugatti	148	128.48	—
,,	,,	Count Czaykowski	Bugatti	148	—	137.77*
27/5/34	,,	G. Moll	Alfa Romeo	146A	127.57	—
,,	,,	A. Momberger	Auto-Union	151	—	140.33*
26/5/35	,,	L. Fagioli	Mercedes-Benz	150	148.83	—
,,	,,	H. Stuck	Auto-Union	151	—	161.88*
30/5/37	,,	H. Lang	Mercedes-Benz	158	162.61	—
,,	,,	B. Rosemeyer	Auto-Union	156	—	172.75*
BELGIAN GRAND PRIX						
28/6/25	(*See European Grand Prix*)					
20/7/30	(*See European Grand Prix*)					
12/7/31	Spa	W. Williams and Count Conelli	Bugatti	143	82.04	—
,,	,,	L. Chiron	Bugatti	143	—	88*
9/7/33	,,	T. Nuvolari	Maserati	149	89.23	92.33*
29/7/34	,,	R. Dreyfus	Bugatti	152	86.9	—
,,	,,	A. Brivio	Bugatti	152	—	96.38*
14/7/35	,,	R. Caracciola	Mercedes-Benz	150	97.8	—
,,	,,	M. von Brauchitsch	Mercedes-Benz	150	—	103.7*
11/7/37	,,	R. Hasse	Auto-Union	156	104.87	—

†Not as text on Page 24.

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
BELGIAN GRAND PRIX *(cont'd.)*						
11/7/37	Spa	H. Lang	Mercedes-Benz	158	—	108.8*
26/6/39	,,	H. Lang	Mercedes-Benz	164	94.39	109.12
BORDINO PRIZE						
22/4/28	Alessandria	T. Nuvolari	Bugatti	139	63.45	—
,,	,,	E. Materassi	Talbot	137	—	64.3*
21/4/29	,,	A. Varzi	Alfa Romeo	131	68.24	68.6*
20/4/30	,,	A. Varzi	Alfa Romeo	131	67.7	70.7*
BRESCIA GRAND PRIX						
12/9/21	Brescia	J. Goux	Ballot	121	90.4	—
,,	,,	P. Bordino	Fiat	124	—	96.31*
500 MILE CHICAGO DERBY						
26/5/15	Chicago Board	D. Resta	Peugeot	116	97.58	—
CHICAGO DERBY						
11/6/16	Chicago Board	D. Resta	Peugeot	116	98.61	—
100 MILE RACE, CHICAGO						
7/8/15	Chicago Board	D. Resta	Peugeot	116	101.86	—
COPPA ACERBO						
17/8/30	Pescara	A. Varzi	Maserati	142	75.35	—
,,	,,	L. Fagioli	Maserati	142	—	78.3*
16/8/31	,,	G. Campari	Alfa Romeo	144	81.68	—
,,	,,	T. Nuvolari	Alfa Romeo	144	—	83.4*
14/8/32	,,	T. Nuvolari	Alfa Romeo	146	86.89	90.3*
13/8/33	,,	L. Fagioli	Alfa Romeo	146	88.03	—
,,	,,	T. Nuvolari	Maserati	149	—	90.4*
15/8/34	,,	L. Fagioli	Mercedes-Benz	150	80.26	—
,,	,,	G. Moll	Alfa Romeo	146A	—	90.5*
15/8/35	,, with chicane	A. Varzi	Auto-Union	153	86.6	90.9*
15/8/36	,,	B. Rosemeyer	Auto-Union	156	86.48	—
,,	,,	A. Varzi	Auto-Union	156	—	89.04
15/8/37	,,	B. Rosemeyer	Auto-Union	156	87.61	92*
14/8/38	,,	R. Caracciola	Mercedes-Benz	160	83.69	—
,,	,,	L. Villoresi	Maserati	161	—	87.79
COPPA CIANO						
21/7/29	Montenero	A. Varzi	Alfa Romeo	131	54.17	—
,,	,,	T. Nuvolari	Alfa Romeo	131	—	55.3*
3/8/30	,,	L. Fagioli	Maserati	142	54.47	

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
COPPA CIANO (*cont'd.*)						
3/8/30	Montenero	T. Nuvolari	Alfa Romeo	131	—	57.2*
31/7/32	,,	T. Nuvolari	Alfa Romeo	146	53.91	54.5
30/7/33	,,	T. Nuvolari	Maserati	149	54.18	55.38
4/8/35	,,	T. Nuvolari	Alfa Romeo	154	55.18	56.22
2/8/36	Leghorn	T. Nuvolari	Alfa Romeo	155	74.8	77.05
7/8/38	,,	H. Lang	Mercedes-Benz	160	85.94	89.17*
,,	,,	M. von Brauchitsch	Mercedes-Benz	160	—	89.17*
COPPA FLORIO						
6/9/08	Bologna	F. Nazzaro	Fiat	109	74.1	—
,,	,,	V. Lancia	Fiat	109	—	82.3*
CORK GRAND PRIX						
23/4/38	Carrigrohane	R. Dreyfus	Delahaye	159	92.5	95.71*
COUPE DE L'AUTO						
21/9/13	Boulogne	G. Boillot	Peugeot	115	63.15	—
,,	,,	J. Goux	Peugeot	115	—	65.5*
CIRCUIT OF CREMONA						
9/6/24	Cremona	A. Ascari	Alfa Romeo	131	98.3	100.8*
CREMONA PRIZE						
24/6/28	Cir. of Cremona	L. Arcangeli	Talbot	137	101.31	—
,,	,,	G. Campari	Alfa Romeo	131	—	108.6*
1/7/29	,,	A. Brilli-Peri	Alfa Romeo	131	114.41	—
,,	,,	A. Maserati	Maserati	141	—	124.4*
CZECHOSLOVAK GRAND PRIX						
27/9/31	Brno	L. Chiron	Bugatti	143	73.26	75.36*
4/9/32	,,	L. Chiron	Bugatti	143	67.67	73.73
17/9/33	,,	L. Chiron	Alfa Romeo	146	63.57	70.8
30/9/34	,,	H. Stuck	Auto-Union	151	79.21	—
,,	,,	L. Fagioli	Mercedes-Benz	150	—	82.29*
29/9/35	,,	B. Rosemeyer	Auto-Union	153	82.39	—
,,	,,	A. Varzi	Auto-Union	153	—	85.21*
26/9/37	,,	R. Caracciola	Mercedes-Benz	158	85.97	94.89*
DONINGTON GRAND PRIX						
2/10/37	Donington	B. Rosemeyer	Auto-Union	156	82.86	85.62*
,,	,,	M. von Brauchitsch	Mercedes-Benz	158	—	85.62*
22/10/38	,,	T. Nuvolari	Auto-Union	162	80.49	83.71
EIFEL RACES (*For lap records see also German Grand Prix*)						
2/6/31	Nürburg Ring	R. Caracciola	Mercedes-Benz	140	67.67	—

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
EIFEL RACES *(cont'd.)*						
29/5/32	Nürburg Ring	R. Caracciola	Alfa Romeo	146	70.7	72.8*
3/6/34	,,	M. von Brauchitsch	Mercedes-Benz	150	76.12	79*
10/6/35	,,	R. Caracciola	Mercedes-Benz	150	72.8	75.6
14/6/36	,,	B. Rosemeyer	Auto-Union	156	72.71	74.46
13/6/37	,,	B. Rosemeyer	Auto-Union	156	82.95	85.13
21/5/39	,,	H. Lang	Mercedes-Benz	164	84.14	86*
ENGLISH GRAND PRIX						
7/8/26	Brooklands with chicanes	R. Senechal and L. Wagner	Delage	136	71.61	—
,,	,,	H. O. D. Segrave	Talbot	137	—	85
1/10/27	,,	R. Benoist	Delage	136A	85.59	—
EUROPEAN GRAND PRIX						
9/9/23	Monza	C. Salamano	Fiat	129	91.06	—
,,	,,	P. Bordino	Fiat	129	—	99.8*
3/8/24	Lyons	G. Campari	Alfa Romeo	131	71	—
,,	,,	H. O. D. Segrave	Sunbeam	132	—	76.7*
28/6/25	Spa	A. Ascari	Alfa Romeo	131	74.56	81.5*
18/7/26	San Sebastian	J. Goux	Bugatti	135	70.4‡	81.5
4/9/27	Monza	R. Benoist	Delage	136A	90.04	94.31
9/9/28	,,	L. Chiron	Bugatti	139	99.4	—
,,	,,	L. Arcangeli	Talbot	137	—	103.2
20/7/30	Spa	L. Chiron	Bugatti	139	72.1	—
FRENCH GRAND PRIX *(For lap records on Rheims circuit see also Marne Grand Prix)*						
26/6/06	Le Mans	Szisz	Renault	100	63	—
,,	,,	P. Baras	R. Brasier	101	—	73.3*
2/7/07	Dieppe	F. Nazzaro	Fiat	104	70.5	—
,,	,,	L. Duray	De Dietrich	102	—	75.4*
7/7/08	Dieppe	C. Lautenschlager	Mercedes	108	69	—
,,	,,	O. Salzer	Mercedes	108	—	78.5*
25/6/12	Dieppe Circuit	G. Boillot	Peugeot	111	68.45	—
,,	,,	D. Bruce Brown	Fiat	112	—	76.8
12/7/13	Amiens	G. Boillot	Peugeot	113	72.2†	—
,,	,,	P. Bablot	Delage	114	—	76.6*

†Not as text on Pages 29 and 34; Goux 2nd at 71.8 m.p.h. ‡Not as table on Page 56.

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
FRENCH GRAND PRIX *(cont'd.)*						
5/7/14	Lyons	C. Lautenschlager	Mercedes	118	65.3†	—
„	„	M. Sailer	Mercedes	118	—	69.95
26/7/21	Le Mans	J. Murphy	Duesenberg	123	78.1	84.0*
16/7/22	Strasbourg	F. Nazzaro	Fiat	126	79.2	—
„	„	P. Bordino	Fiat	126	—	87.75*
2/6/23	Tours	H. O. D. Segrave	Sunbeam	128	75.3‡	—
„	„	P. Bordino	Fiat	129	—	87.75*
3/8/24	*(See European Grand Prix)*					
26/7/25	Montlhery	A. Divo and R. Benoist	Delage	134	69.7	—
„	„	A. Divo	Delage	134	—	80.3*
27/6/26	Miramas	J. Goux	Bugatti	139	68.2	79.4*
3/7/27	Montlhery	R. Benoist	Delage	136A	77.24	81.43*
30/6/29	Le Mans	W. Williams	Bugatti	139	82.66	52.7*
21/9/30	Pau	P. Etancelin	Bugatti	139	90.4	—
21/6/31	Montlhery	L. Chiron and A. Varzi	Bugatti	143	78.21	—
„	„	L. Fagioli	Maserati	142	—	85.6*
3/7/32	Rheims	T. Nuvolari	Alfa Romeo	146	92.26	99.5*
11/6/33	Montlhery	G. Campari	Maserati	149	81.52	86.6*
1/7/34	„	L. Chiron	Alfa Romeo	146A	85.55	91.44*
23/6/35	„ with chicanes	R. Carracciola	Mercedes-Benz	150	77.39	—
„	„	T. Nuvolari	Alfa Romeo	154	—	85*
3/7/38	Rheims	M. von Brauchitsch	Mercedes-Benz	160	101.3	—
„	„	H. Lang	Mercedes-Benz	160	—	105.87*
9/7/39	„	H. Muller	Auto-Union	163	105.25	—
„	„	H. Lang	Mercedes-Benz	164	—	114.87*
GERMAN GRAND PRIX *(For lap records see also Eifel Races)*						
15/7/28	Nürburg Ring	R. Caracciola	Mercedes-Benz	140	64.6	69.34*
14/7/29	„	L. Chiron	Bugatti	139	66.79	69.97*
19/7/31	„	R. Caracciola	Mercedes-Benz	140	67.4	—
„	„	A. Varzi	Bugatti	143	—	72.6*
17/7/32	„	R. Caracciola	Alfa Romeo	146	74.13	—

†Not as text on Pages 29 and 37; Wagner 2nd at 65.1 m.p.h.; Salzer 3rd at 64.6 m.p.h. ‡Not as text on Page 48.

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
GERMAN GRAND PRIX (*cont'd.*)						
17/7/32	Nürburg Ring	T. Nuvolari	Alfa Romeo	146	—	77.55*
15/7/34	,,	H. Stuck	Auto-Union	151	76.39†	79.29*
28/7/35	,,	T. Nuvolari	Alfa Romeo	154	75.43	—
,,	,,	M. von Brauchitsch	Mercedes-Benz	150	—	80.73*
26/7/36	,,	B. Rosemeyer	Auto-Union	156	81.8	85.52*
25/7/37	,,	R. Caracciola	Mercedes-Benz	158	82.77	—
,,	,,	B. Rosemeyer	Auto-Union	156	—	85.57*
24/7/38	,,	R. Seaman	Mercedes-Benz	160	80.75	83.76
23/7/39	,,	R. Caracciola	Mercedes-Benz	164	75.12	81.66
HARKNESS TROPHY						
28/10/16	Sheepshead Bay Track	J. Aitken	Peugeot	116	105.95	—
HUNGARIAN GRAND PRIX						
21/6/36	Budapest	T. Nuvolari	Alfa Romeo	155	69.1	71.84*
500 MILE SWEEPSTAKE						
30/5/13	Indianapolis	J. Goux	Peugeot	111	75.92	—
,,	,,	P. Zuccarelli	Peugeot	111	—	93.5*
30/5/14	,,	R. Thomas	Delage	114	82.47	—
,,	,,	G. Boillot	Peugeot	113	—	99.5*
30/5/15	,,	R. de Palma	Mercedes	118	89.84	98.6
30/5/16	,,(300 mls.)	D. Resta	Peugeot	116	83.26	—
30/5/19	,,	H. Wilcox	Peugeot	116	87.95	—
,,	,,	R. Thomas	Ballot	119	—	104.7*
30/5/20	,,	G. Chevrolet	Monroe	120	88.5	—
,,	,,	R. de Palma	Ballot	121	—	99.15
30/5/21	,,	T. Milton	Frontenac	122	89.62	—
,,	,,	R. de Palma	Ballot	121	—	100.75
30/5/22	,,	J. Murphy	Murphy Special	—	94.48	100.5
30/5/23	,,	T. Milton	H. C. S. Miller	127	90.95	108.17*
ITALIAN GRAND PRIX						
3/9/22	Monza	P. Bordino	Fiat	126	86.89	91.3*
9/9/23	(*See European Grand Prix*)					
19/10/24	Monza	A. Ascari	Alfa Romeo	131	98.76	104.24*
6/9/25	,,	Count G. Brilli-Peri	Alfa Romeo	131	94.76	—
,,	,,	P. Kreis	Duesenberg	—	—	103.21

†Not as table on Page 76.

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
ITALIAN GRAND PRIX (*cont'd.*)						
5/9/26	Monza	Sabipa	Bugatti	135	85.87	—
,,	,,	M. Costantini	Bugatti	135	—	98.3
4/9/27	(*See European Grand Prix*)					
9/9/28	(*See European Grand Prix*)					
24/5/31	Monza	G. Campari and T. Nuvolari	Alfa Romeo	144	96.17	105*
5/6/32	,,	T. Nuvolari	Alfa Romeo	146	104.13	—
5/6/32	,,	L. Fagioli	Maserati	147	—	112.22*
10/9/33	Full Monza	L. Fagioli	Alfa Romeo	146	108.58	115.82*
9/9/34	2.68 Miles at Monza	R. Caracciola and L. Fagioli	Mercedes-Benz	150	65.37	—
,,	,,	H. Stuck	Auto-Union	151	—	72.59*
8/9/35	2.68 Miles at Monza	H. Stuck	Auto-Union	153	85.17†	—
,,	,,	T. Nuvolari	Alfa Romeo	155	—	90.77*
13/9/36	Monza with chicanes	B. Rosemeyer	Auto-Union	156	84.59	87.18*
12/9/37	Leghorn	R. Caracciola	Mercedes-Benz	158	81.59	84.5*
11/9/38	Monza with chicanes	T. Nuvolari	Auto-Union	162	96.7	—
,,	,,	H. Lang	Mercedes-Benz	160	—	101.38
KAISER PRIZE						
14/6/07	Taunus Mountains	F. Nazzaro	Fiat	—	52.5	—
MARNE GRAND PRIX (*For lap records see also French Grand Prix*)						
5/7/28	Rheims	L. Chiron	Bugatti	139	82.5	91.4*
14/7/29	,,	P. Etancelin	Bugatti	139	85.5	88.6
29/6/30	,,	R. Dreyfus	Bugatti	139	88.5	91
5/7/31	,,	P. Lehoux	Bugatti	143	89.49	92.78*
2/7/33	,,	P. Etancelin	Alfa Romeo	144	90.59	—
,,	,,	G. Campari	Maserati	149	—	96
8/7/34	,,	L. Chiron	Alfa Romeo	146A	90.71	—
,,	,,	A. Varzi	Alfa Romeo	146A	—	97.65
7/7/35	,,	R. Dreyfus	Alfa Romeo	146A	98.03	102*
MILAN GRAND PRIX						
4/9/27	Monza	P. Bordino	Fiat	138	94.57	96.59

†Not as table on Page 83.

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
MILAN CIRCUIT						
28/6/36	Milan	T. Nuvolari	Alfa Romeo	155	60.02	—
,,	,,	A. Varzi	Auto-Union	156	—	62.26*
MONACO GRAND PRIX						
14/4/29	Monte Carlo	W. Williams	Bugatti	139	50.23	52.7
6/4/30	,,	R. Dreyfus	Bugatti	139	53.63†	56.01*
19/4/31	,,	L. Chiron	Bugatti	143	54.09	56.01
17/4/32	,,	T. Nuvolari	Alfa Romeo	144	55.81	—
,,	,,	A. Varzi	Bugatti	143	—	58.3*
3/4/33	,,	A. Varzi	Bugatti	143	57.04	59.77*
2/4/34	Monte Carlo	G. Moll	Alfa Romeo	146A	55.86	—
,,	,,	Count Trossi	Alfa Romeo	146A	—	59.7*
22/4/35	,,	L. Fagioli	Mercedes-Benz	150	58.17	60.08*
13/4/36	,,	R. Caracciola	Mercedes-Benz	157	51.69	—
13/4/36	,,	H. Stuck	Auto-Union	156	—	56.01*
8/8/37	,,	M. von Brauchitsch	Mercedes-Benz	158	63.25	—
,,	,,	R. Caracciola	Mercedes-Benz	158	—	66.99*
MONTENERO PRIZE						
19/8/28	Montenero	E. Materassi	Talbot	137	52.77	—
,,	,,	T. Nuvolari	Bugatti	139	—	53.8*
MONZA GRAND PRIX						
15/9/29	2.8 Mile Circuit of Monza	A. Varzi	Alfa Romeo	131	116.83	—
,,	,,	A. Maserati	Maserati	141	—	124.2*
7/9/30	4.3 Mile Lap Monza	A. Varzi	Maserati	142	93.55	100,6*
6/9/31	,,	L. Fagioli	Maserati	142	96.6	—
,,	,,	T. Nuvolari	Alfa Romeo	144	—	101.23*
11/9/32	Monza	R. Caracciola	Alfa Romeo	146	110.8	—
,,	,,	T. Nuvolari	Alfa Romeo	146	—	113.7
10/9/33	2.8 Mile Lap Monza	P. Lehoux	Bugatti	143	108.99	—
,,	,,	Count Czaykowski	Bugatti	148	—	116.81
PAU GRAND PRIX						
10/4/38	Pau	R. Dreyfus	Delahaye	159	54.64	—
,,	,,	R. Caracciola	Mercedes-Benz	150	—	57.86*
2/4/39	,,	H. Lang	Mercedes-Benz	164	56.09	—
,,	,,	M. von Brauchitsch	Mercedes-Benz	164	—	57.83

†Not as table on Page 62 and text Page 66.

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
PENYA RHIN						
17/6/34	Mont Juich	A. Varzi	Alfa Romeo	146A	64.24	—
,,	,,	L. Chiron	Alfa Romeo	146A	—	66.25*
17/6/35	,,	L. Fagioli	Mercedes-Benz	150	66.99	—
,,	,,	R. Caracciola	Mercedes-Benz	150	—	68.94*
7/6/36	,,	T. Nuvolari	Alfa Romeo	155	69.21	71.85*
RIO DE JANEIRO GRAND PRIX						
6/6/37	Gavea	C. Pintacuda	Alfa Romeo	155	51.5	—
ROME GRAND PRIX						
10/6/28	Trefontana	L. Chiron	Bugatti	139	78.55	80.4
26/5/29	,,	A. Varzi	Alfa Romeo	131	80.2	—
25/5/30	,,	L. Arcangeli	Maserati	142	83.6	—
,,	,,	G. Bouriat	Bugatti	139	—	86.6*
SARTHE GRAND PRIX or G.P. de FRANCE						
23/7/11	Le Mans	V. Hemery	Fiat	110	56.71	67.75*
9/9/12	,,	J. Goux	Peugeot	111	74.56	—
,,	,,	G. Boillot	Peugeot	111	—	80*
5/8/13	,,	P. Bablot	Delage	114	76.8	82.5*
SAN SEBASTIAN GRAND PRIX						
25/9/24	San Sebastian	H. O. D. Segrave	Sunbeam	132	64.12	—
,,	,,	M. Costantini	Bugatti	133	—	69.79*
19/9/25	,,	A. Divo	Delage	134	76.4	—
,,	,,	M. Costantini	Bugatti	133	—	82.75*
28/7/28	,,	L. Chiron	Bugatti	139	80.58	88.25*
SPANISH GRAND PRIX						
31/7/27	San Sebastian	R. Benoist	Delage	136A	80.52	85.41*
4/10/30	,,	A. Varzi	Maserati	142	86.82	91.09*
24/9/33	,,	L. Chiron	Alfa Romeo	146	83.32	—
,,	,,	T. Nuvolari	Maserati	149	—	96.59*
23/9/34	,,	L. Fagioli	Mercedes-Benz	150	97.13	—
,,	,,	H. Stuck	Auto-Union	151	—	101.96*
22/9/35	,,	R. Caracciola	Mercedes-Benz	150	101.92	—
,,	,,	A. Varzi	Auto-Union	153	—	108.11*

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
SWISS GRAND PRIX						
26/8/34	Berne	H. Stuck	Auto-Union	151	87.21	—
,,	,,	A. Momberger	Auto-Union	151	—	94.42*
25/8/35	,,	R. Caracciola	Mercedes-Benz	150	89.95	—
,,	,,	L. Fagioli	Mercedes-Benz	150	—	99.5*
23/8/36	,,	B. Rosemeyer	Auto-Union	156	100.45	105.42*
22/8/37	,,	R. Caracciola	Mercedes-Benz	158	98.61†	107.14* (P)
21/8/38	,,	R. Caracciola	Mercedes-Benz	160	89.44	—
,,	,,	R. Seaman	Mercedes-Benz	160	—	95.35
						103 (P)
20/8/39	,,	H. Lang	Mercedes-Benz	164	96.02	106.23 (P)
,,	,,	R. Caracciola	Mercedes-Benz	164	—	104.32
TARGA FLORIO						
23/11/19	Madonie	A. Boillot	Peugeot	117	34.19	—
27/4/24	,,	C. Werner	Mercedes	130	41.02	42.4*
3/5/25	,,	M. Costantini	Bugatti	133	44.5	45.1*
25/4/26	,,	M. Costantini	Bugatti	139	45.68	46.8*
24/4/27	,,	E. Materassi	Bugatti	139	44.61	—
,,	,,	F. Minoia	Bugatti	139	—	46.78
6/5/28	,,	A. Divo	Bugatti	139	45.65	—
,,	,,	L. Chiron	Bugatti	139	—	46.2
5/5/29	,,	A. Divo	Bugatti	139	46.21	—
,,	,,	F. Minoia	Bugatti	139	—	47.3*
4/5/30	,,	A. Varzi	Alfa Romeo	131	48.48	49.1*
10/5/31	Long Madonie	T. Nuvolari	Alfa Romeo	144	40.39	—
,,	,,	A. Varzi	Bugatti	143	—	43.8*
8/5/32	New Short Madonie	T. Nuvolari	Alfa Romeo	144	49.27	50.7*
28/5/33	,,	A. Brivo	Alfa Romeo	144	47.56	—
,,	,,	I. Borzachini	Alfa Romeo	144	—	49.6
R.A.C. T.T.						
10/6/14	Isle of Man	A. Lee Guinness	Sunbeam	115A	56.44	59.3*
22/6/22	,,	J. Chassagne	Sunbeam	125	55.78	—
,,	,,	H. O. D. Segrave	Sunbeam	125	—	62.5* (P)
TRIPOLI						
7/5/33	Mellaha	A. Varzi	Bugatti	143	104.7	110*
6/5/34	,,	A. Varzi	Alfa Romeo	146A	115.67	—

†Not as table on Page 92.

Date	Course	Driver	Car	Index No.	Winning Speed m.p.h.	Lap Speed (Rec'd*)
TRIPOLI (*cont'd.*)						
6/5/34	Mellaha	L. Chiron	Alfa Romeo	146A	—	124.48*
12/5/35	„	R. Caracciola	Mercedes-Benz	150	123.03	136.81*
10/5/36	„	A. Varzi	Auto-Union	156	129.01	141.29*
9/5/37	„	H. Lang	Mercedes-Benz	158	134.42	—
„	„	H. Stuck	Auto-Union	156	—	142.44*
15/5/38	„	H. Lang	Mercedes-Benz	160	127.4	139.7
„	„	Count Trossi	Maserati	161	—	131.2 (P)
TUNIS GRAND PRIX						
5/5/35	Carthage	A. Varzi	Auto-Union	153	101.2	105.17*
17/5/36	„	R. Caracciola	Mercedes-Benz	157	99.62	—
„	„	B. Rosemeyer	Auto-Union	156	—	103.79*
VANDERBILT TROPHY						
12/10/36	Roosevelt Speedway	T. Nuvolari	Alfa Romeo	155	65.99	69.92*
5/7/37	Roosevelt Field	B. Rosemeyer	Auto-Union	156	82.56	— (P)
„	„	R. Caracciola	Mercedes-Benz	158	—	84.5*
YUGOSLAV GRAND PRIX						
3/9/39	Belgrade	T. Nuvolari	Auto-Union	163	81.21	83.9*
„	„	M. von Brauchitsch	Mercedes-Benz	164	—	83.9*

NOTE.—*The INDEX NUMBER refers to a table of specifications included in the Appendices of Vol. II.*

MAKES AND TYPES OF CAR WITH MORE THAN THREE WINS IN MAJOR EUROPEAN ROAD RACES LISTED ABOVE

Bugatti Types 35B and C and Type 39	21
Alfa Romeo P3	16
Alfa Romeo P2	12
Mercedes-Benz W25	11
Bugatti Type 51 Auto-Union Type C	10
Mercedes-Benz W154/163	9
Maserati 2.5/2.8-litre Alfa Romeo 2.3-litre Monza	6
Alfa Romeo 3.8-litre Mercedes-Benz Type W125 Delage 1½-litre	5
Auto-Union Type D	4
Auto-Union Type A Mercedes-Benz SSK Maserati 2.9-litre	3

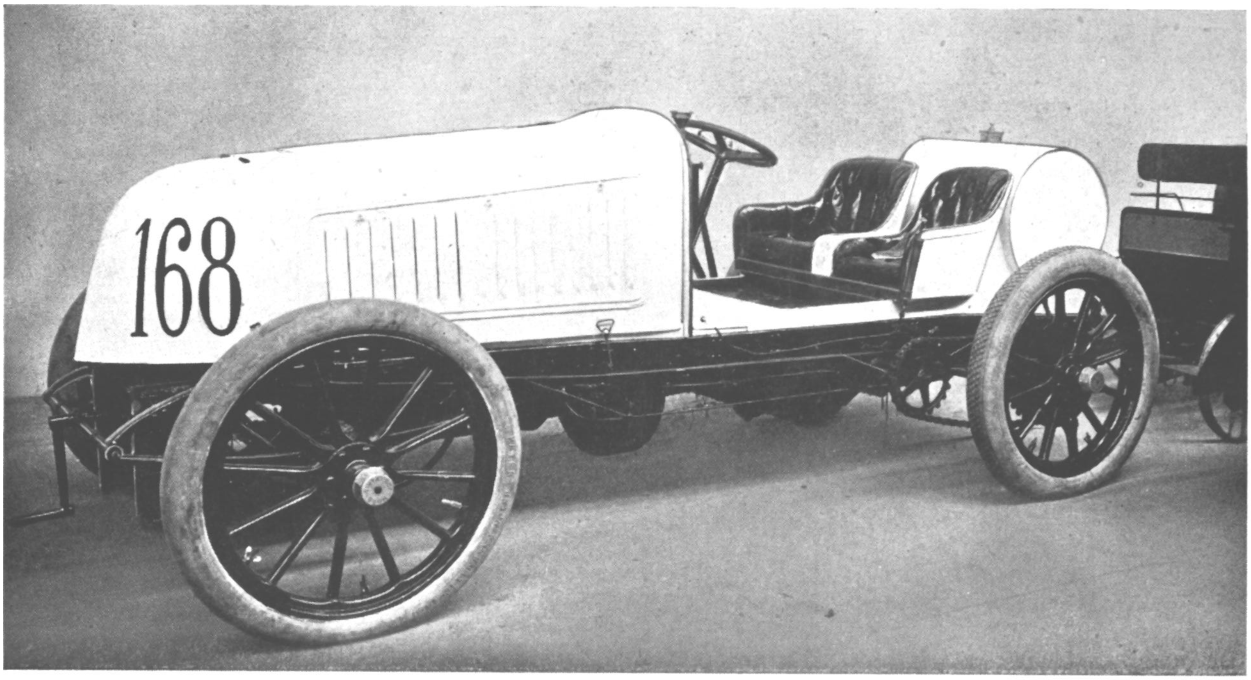
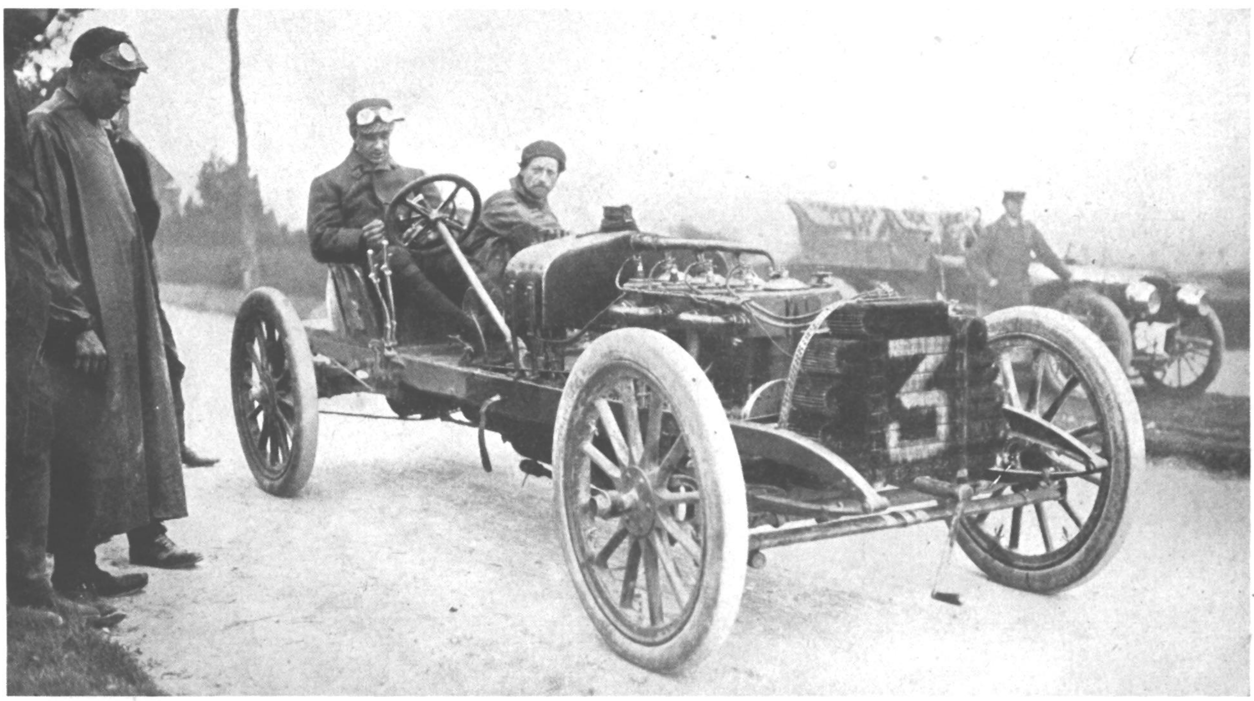
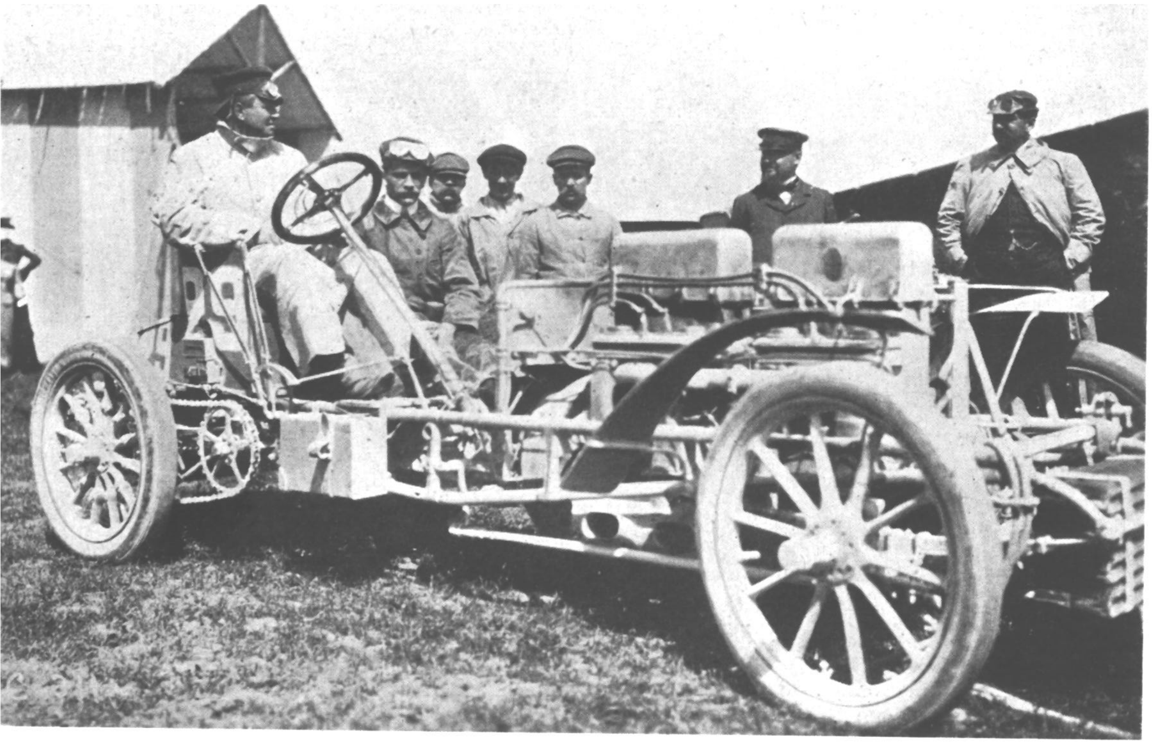


PLATE XXX

LAST OCCASION - The 1903 Dauphin Mors won the last town to town race, the famous Paris-Madrid which was stopped by authority at Bordeaux. This car had a four-cylinder, 11.5-litre, engine developing 70 b.h.p. and technical features disclosed in this photograph include the low mounted radiator, placed outside the tapering bonnet, and the struts running beneath the frame to give this component increased beam stiffness.



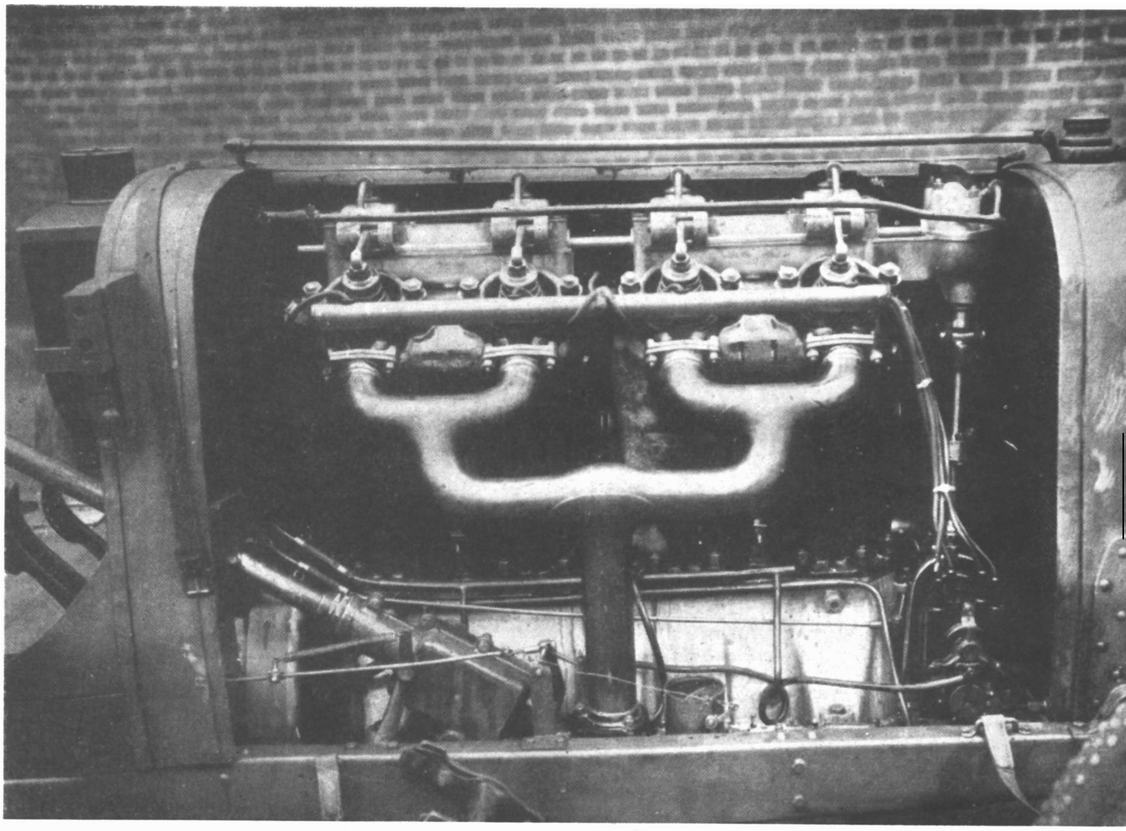
REDUCING WIND RESISTANCE - This 1904 Clement Bayard shows an early attention to low wind resistance. The picture of the car in chassis form indicates the header tank mounted behind the cylinder block with low-level radiator tubes ; the fairing over the track rod and front axle is also interesting. It is instructive to compare the rake on the steering column with the Mors shown above.



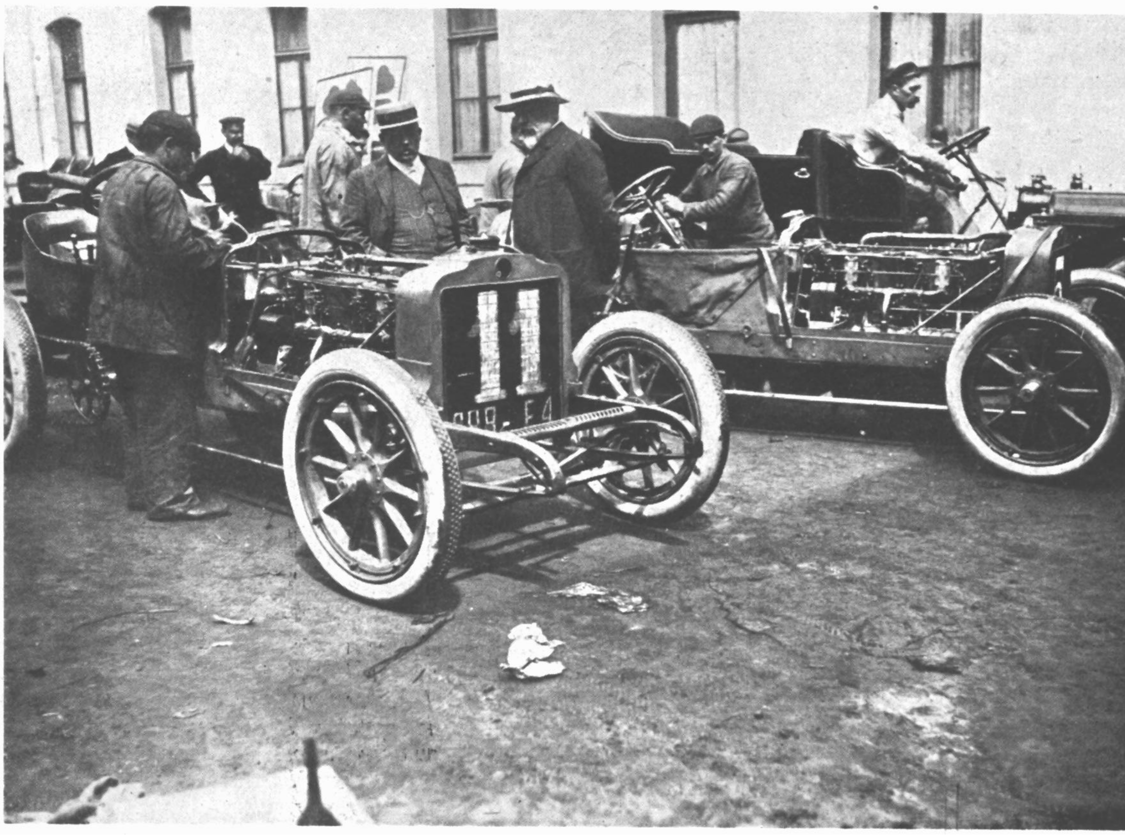
HETERODOX COMBINATION - Probably the fastest car of the pre-Grand Prix period was the opposed piston Gobron Brillié which in 1904 was the first I.C. engined car officially to exceed 100 m.p.h. Alcohol mixture was used and other advanced features included the girder-type tubular frame and forward mounted radiator element mounted at the position of maximum pressure.

EARLY INCLINATION - Early use of inclined overhead valves operated by pushrods with two camshafts at crankshaft level is exemplified by this Pipe car driven by Jenatzy in the 1907 Circuit des Ardennes. The design was originally employed by this Company in 1904.

PLATE
XXXII



FASTEST KILOMETRE - The highest speed achieved over a flying km. during the 1908 French Grand Prix was 104.8 m.p.h. achieved by Rigal driving a four-cylinder (155 mm. by 185 mm.) Clément Bayard developing 135 h.p. from 11.7 litres. Engine design:was notable for the use of inclined overhead valves and an overhead camshaft and driven from a vertical shaft and bevel gears at the front of the engine,



STEADY PROGRESS - Amongst the fastest road racing cars in the 1908 G.P. were the Richard Brasiers shown in this picture. One of these cars was timed to cover a measured distance in the race at 101.3 m.p.h. The engine was a four-cylinder of 12 litres capacity giving 120 b.h.p. The general similarity in design between 1903 and 1908 is shown clearly by these first six photographs.

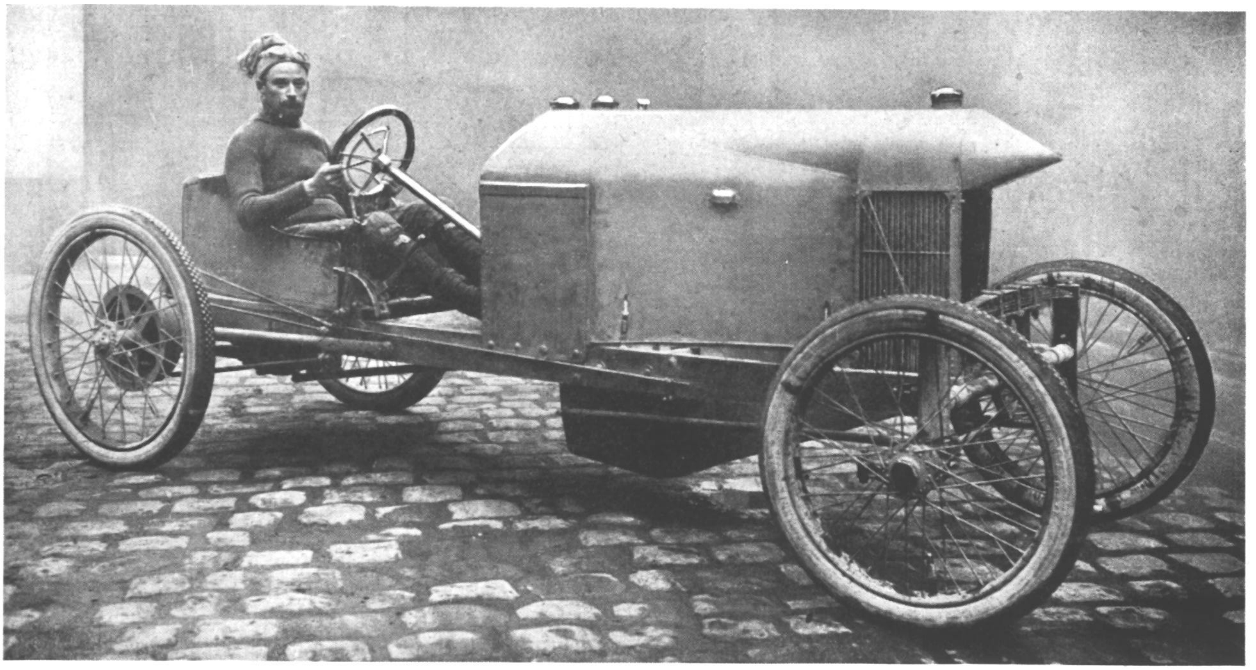
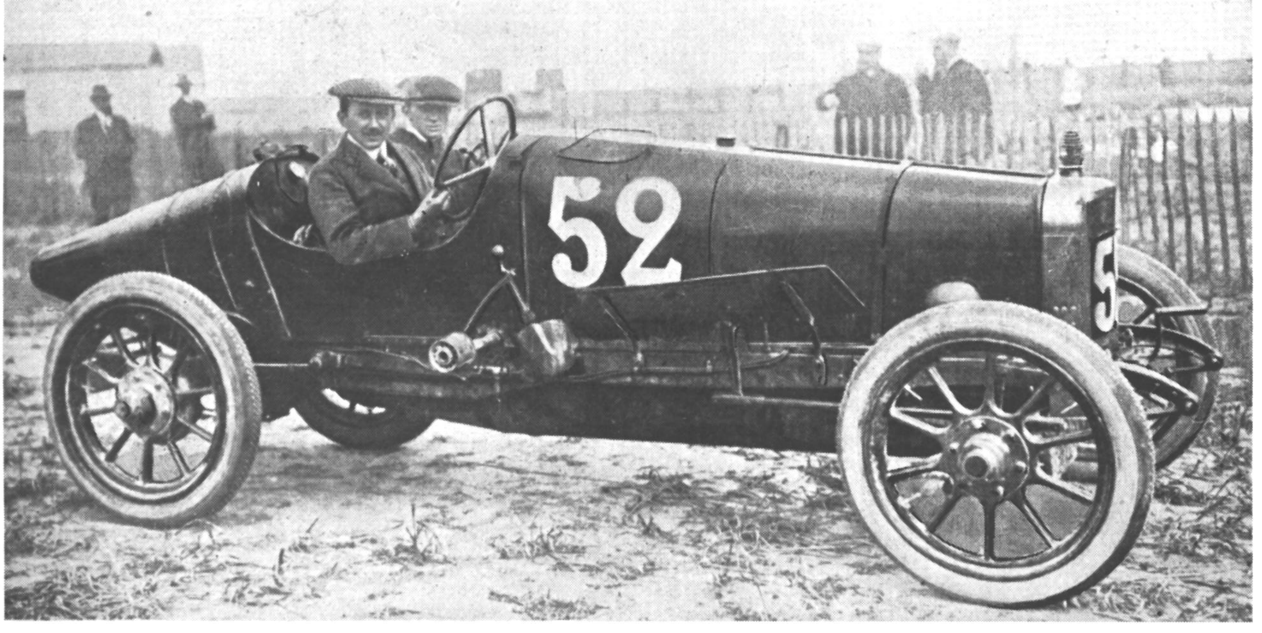
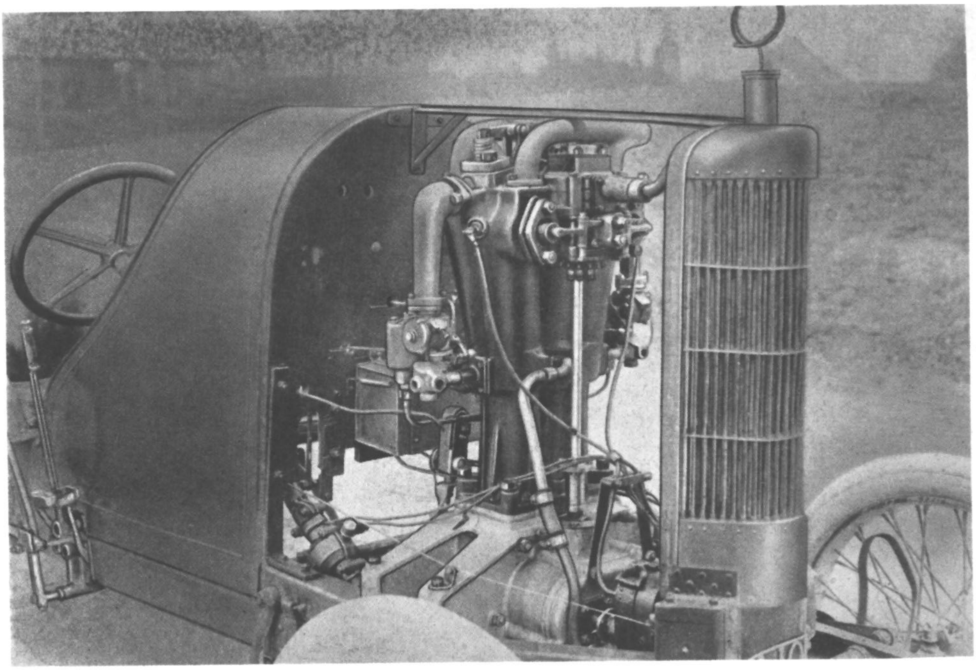


PLATE XXXIII

INNOVATION - Independent suspension to the front wheels was first used for racing in the Voiturette cars built by Sizaire-Naudin in 1906. The wheels were attached to sliding members which connected to a transverse leaf spring, an arrangement providing vertical rise and fall of the wheels with elimination of gyroscopic reactions. The abnormal bonnet height of' the 1908 car here shown was the result of piston area limitations leading to an S/B ratio of' 2.5 : 1.

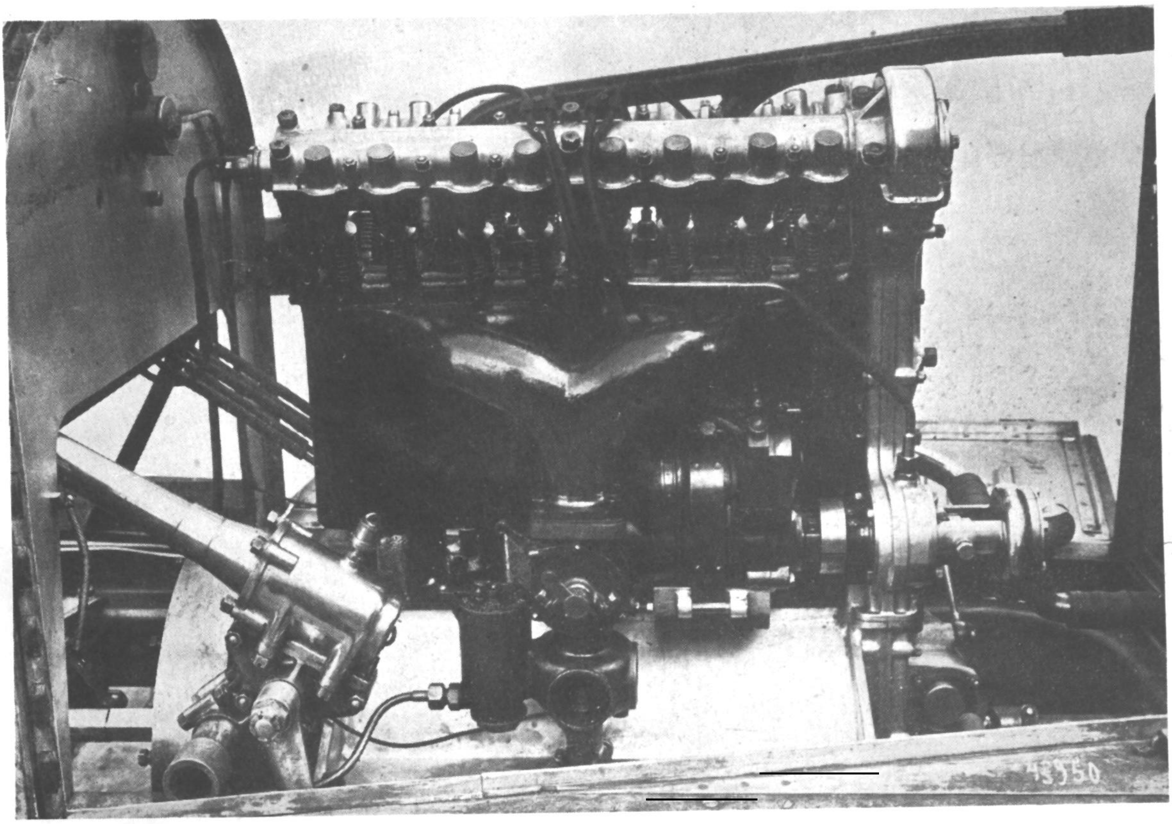


FIVE YEARS' DEVELOPMENT - By 1912 progress in small car design had been so great that in the French Grand Prix of that year the British cars using 3-litre engines running at 3,000 r.p.m. and developing 65 and 75 h.h.p. were but little slower than cars running in the class in which there were no limits on engine capacity. In a two-day race a Sunbeam similar to the car pictured above finished third at an average speed of 65.3 m.p.h. (and was timed at 84.73 m.p.h.) and during the first day Vauxhall cars of basically similar conception had also challenged their larger rivals.

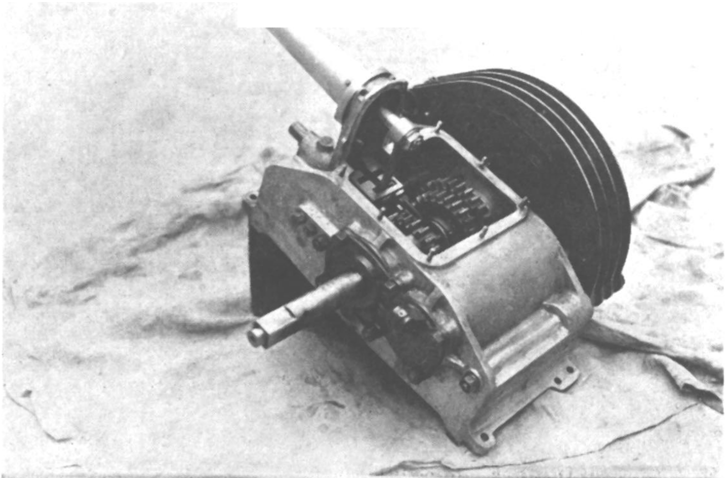


IN EXTREMIS - As a result of successive annual regulations limiting piston area, the Lion-Peugeot voiturette racing cars of 1910 were fitted with this Vee-twin engine with a bore and stroke of 80 mm. by 280 mm. and a capacity of 2.8 litres. Having three valves per cylinder, this engine developed approximately 40 h.p. at 2,200 r.p.m. the equivalent of the very high piston speed of 4,000 ft./min.

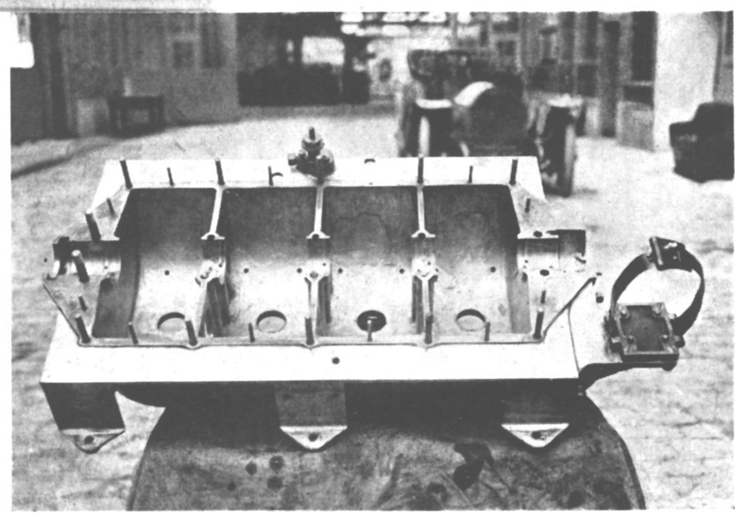
PLATE XXXIV



PRIME EXAMPLE - Probably the most efficient engine built before 1914 was this 1913 3-litre Peugeot with bore and stroke of 78 mm. by 156 mm. Having four valves per cylinder, operated by two overhead camshafts gear driven from the front of the engine, it developed approximate(v 90 b.h.p. at 2,900 r.p.m.



BASIC ENGINEERING - The 1912, 7.6-litre, Grand Prix Peugeot which won the French Grand Prix was very carefully designed and these two photographs show the compact four-speed gearbox with large ribbed transmission brake and the bottom half of the crankcase showing support for five main crankshaft bearings.



RADICAL CHANGE - Racing car performance, and indeed the whole technique of race driving, was much affected by front-wheel brakes which were first used on the road in the French Grand Prix of 1914. The Perrot design employed by Delage is illustrated in this picture: this basic type was continued on many racing cars for a further 20 years.

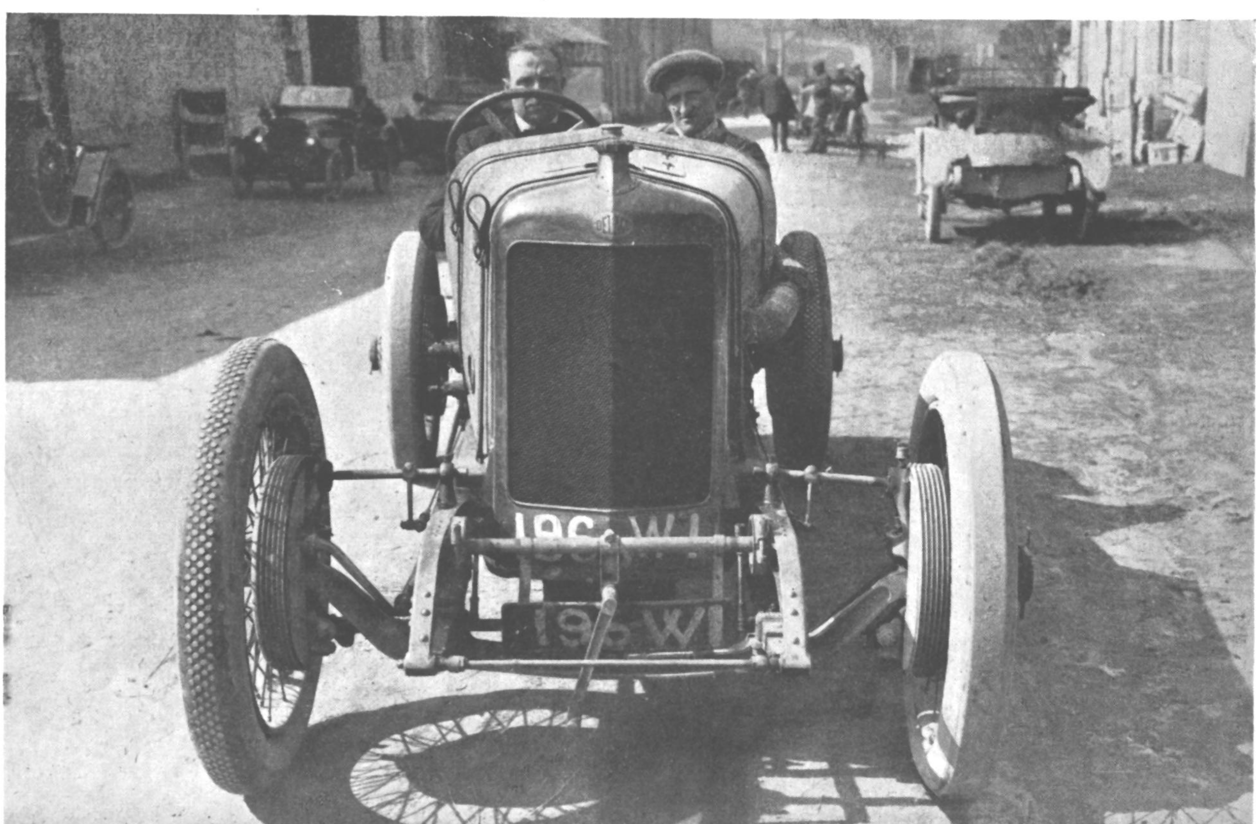
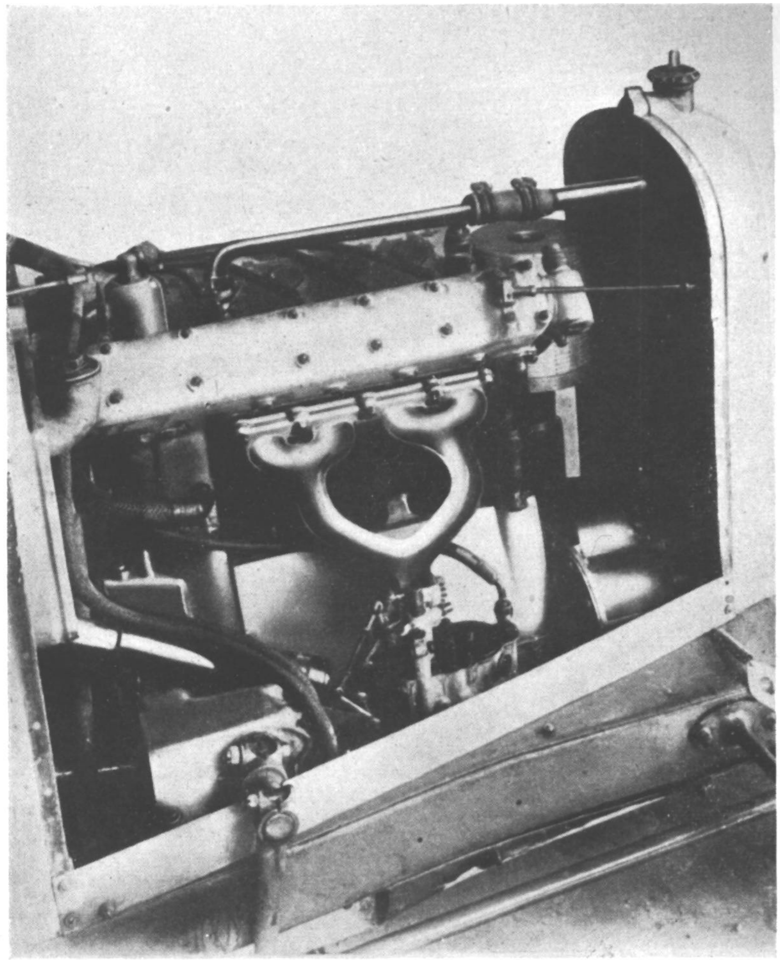
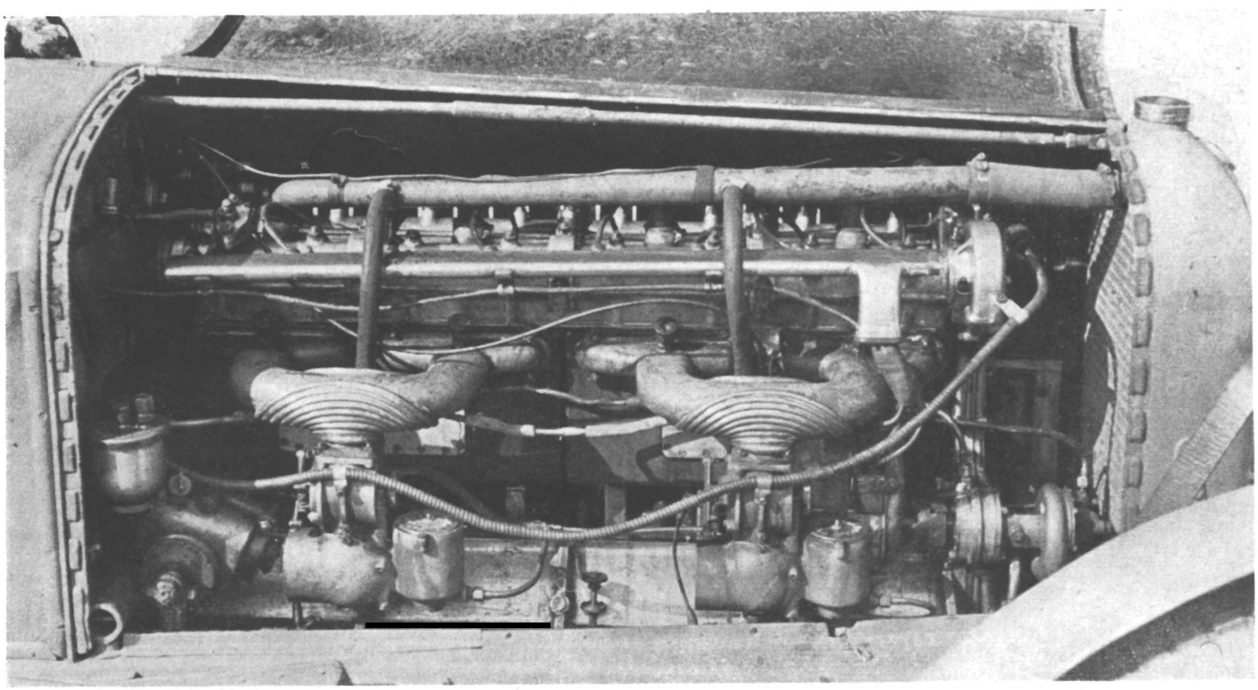


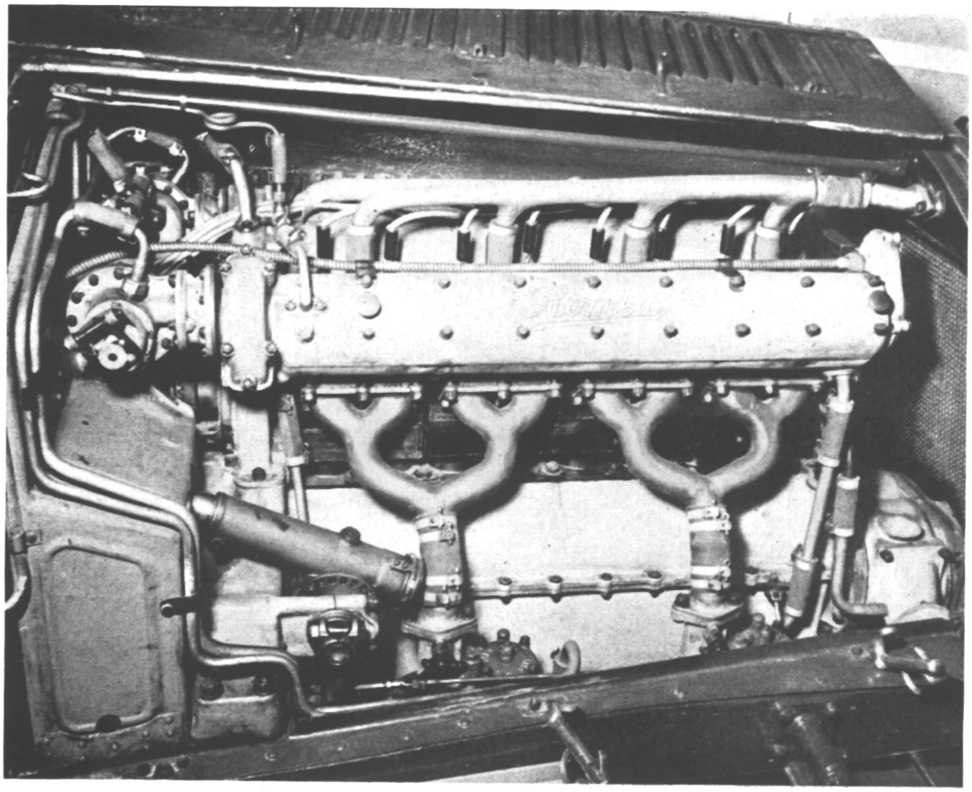
PLATE XXXVI



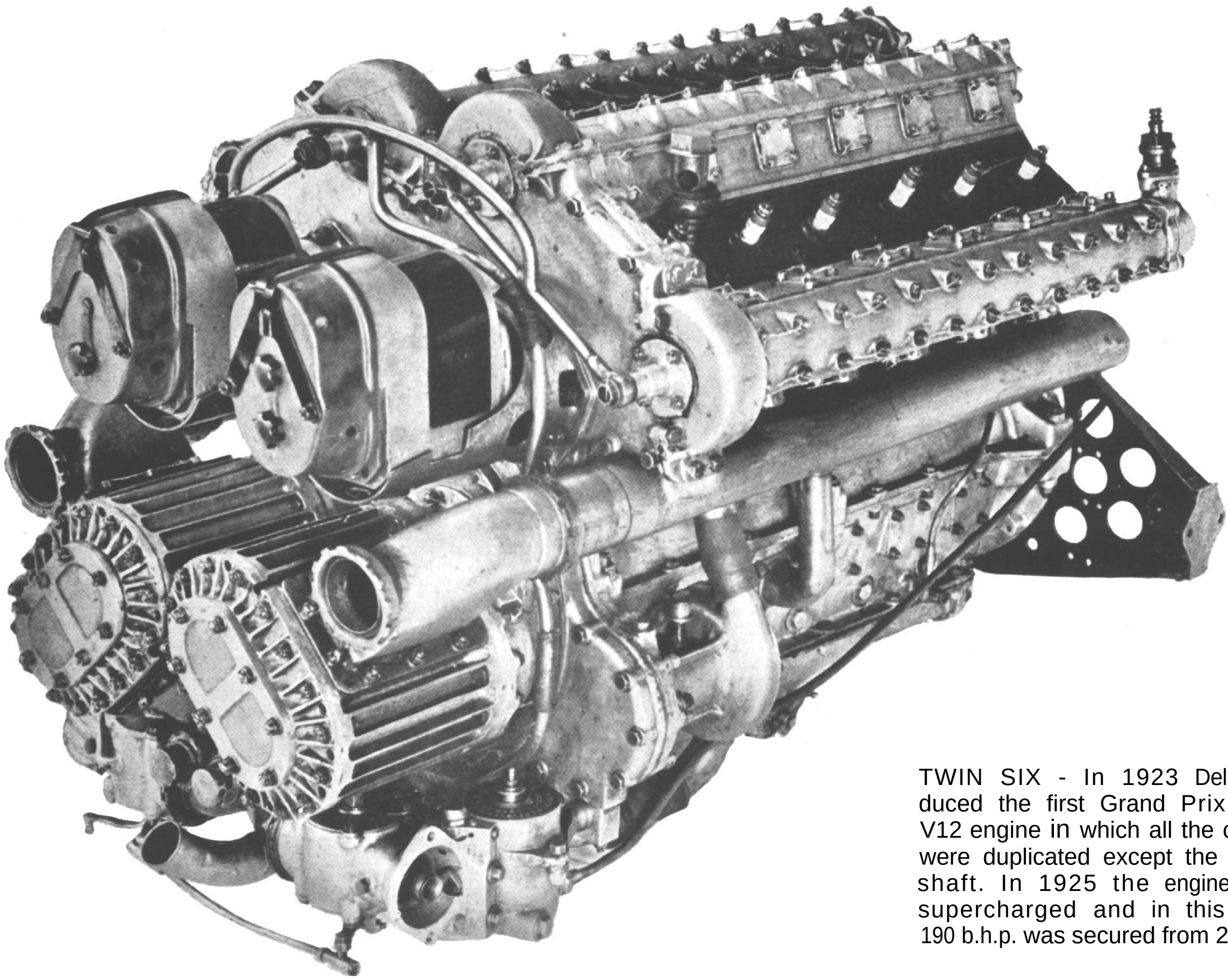
POWER BOOST - The earliest road racing cars to use supercharging were the Chadwick in 1907, in the U.S.A. and Mercedes (1921) in Europe. The first successful Grand Prix car to employ forced induction was the 2-litre Fiat which won the Italian Grand Prix of 1923. This photograph shows the very similar four-cylinder, 1½-litre, Fiat jirst built in 1922 and supercharged in 1923. The Roots blower was driven directly from the nose of the crankshaft and inspired air through a large air filter ; the carburetter received air under pressure of *circa* 5 lb. per square inch.



MULTI-CYLINDER - Eight-cylinder, in-line, engines were first used in Grand Prix racing in 1908 but eleven years elapsed before success attended this arrangement with the production by Ballot of a Henri-designed 4.9-litre car in 1919. After being designed and built in 101 days this car raised the lap record on the Indianapolis circuit by nearly 5 m.p.h.



STRAIGHT-EIGHT DEVELOPMENT - The 2-litre P2 Alfa Romeo first raced in 1924 was a brilliant example of the Italian school of design and was the most successful road racing car in Europe for the next five years. This photoqaph shows the welded steel cylinder block (formed in sets of two) with 100 degree angle valves worked by rear-positioned timing gears. The Roots type blower can be seen at the front of the crankcase, pressure air being delivered to the carburetters. At its peak this engine developed 165 b.h.p.



TWIN SIX - In 1923 Delage produced the first Grand Prix type V12 engine in which all the organs were duplicated except the crankshaft. In 1925 the engine was supercharged and in this form 190 b.h.p. was secured from 2 litres.

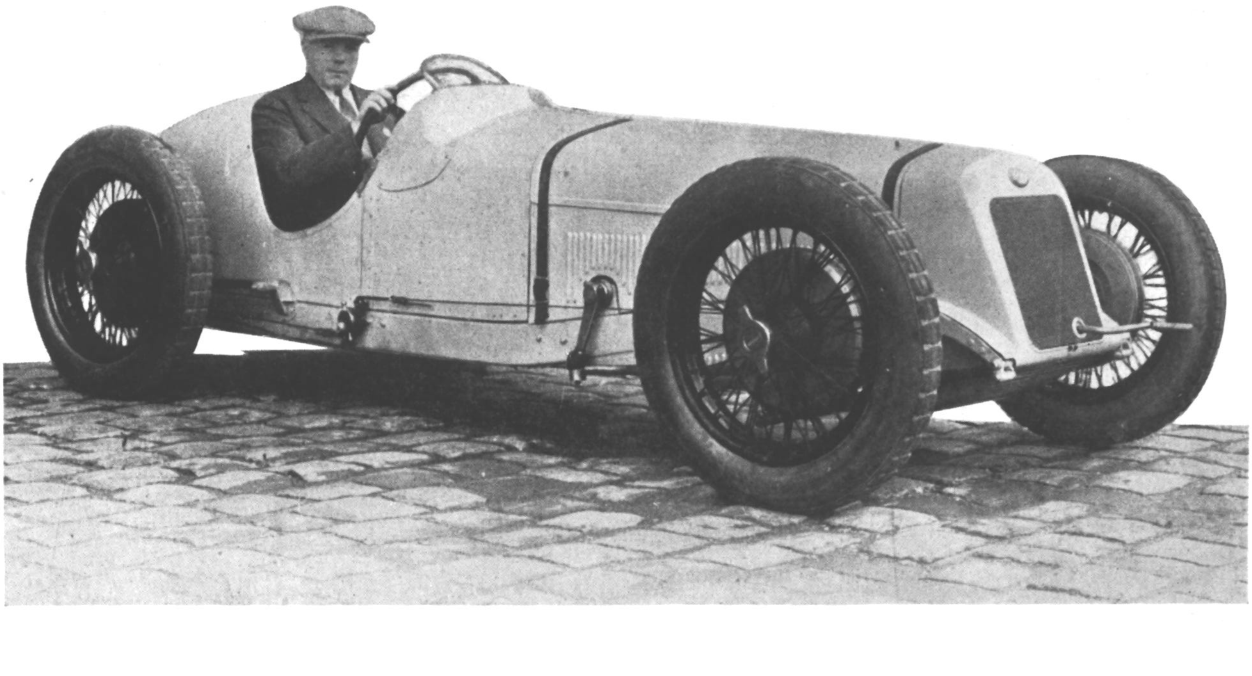
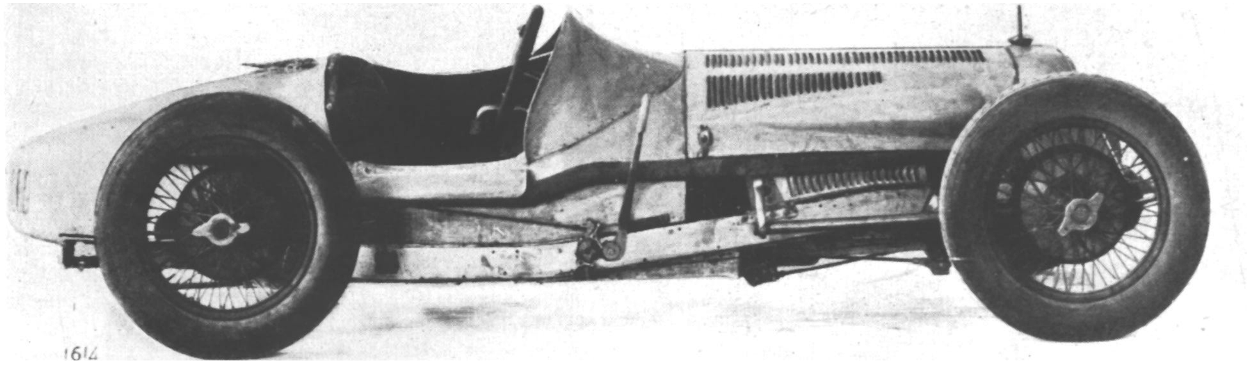


PLATE XXXVIII

LOW LEVEL - Designers counter-attacked the restriction of engine capacity to 1½ litres in the 1926/7 period by reducing windage and frontal area to a minimum. As the regulations for these years did not require a mechanic to be carried on the car the driver was placed very low to one side with offset transmission lines and double drop frames. The pictures on this page show the eight-cylinder, in-line, Delage, above, and the twelve-cylinder Fiat with geared crankshafts, below.



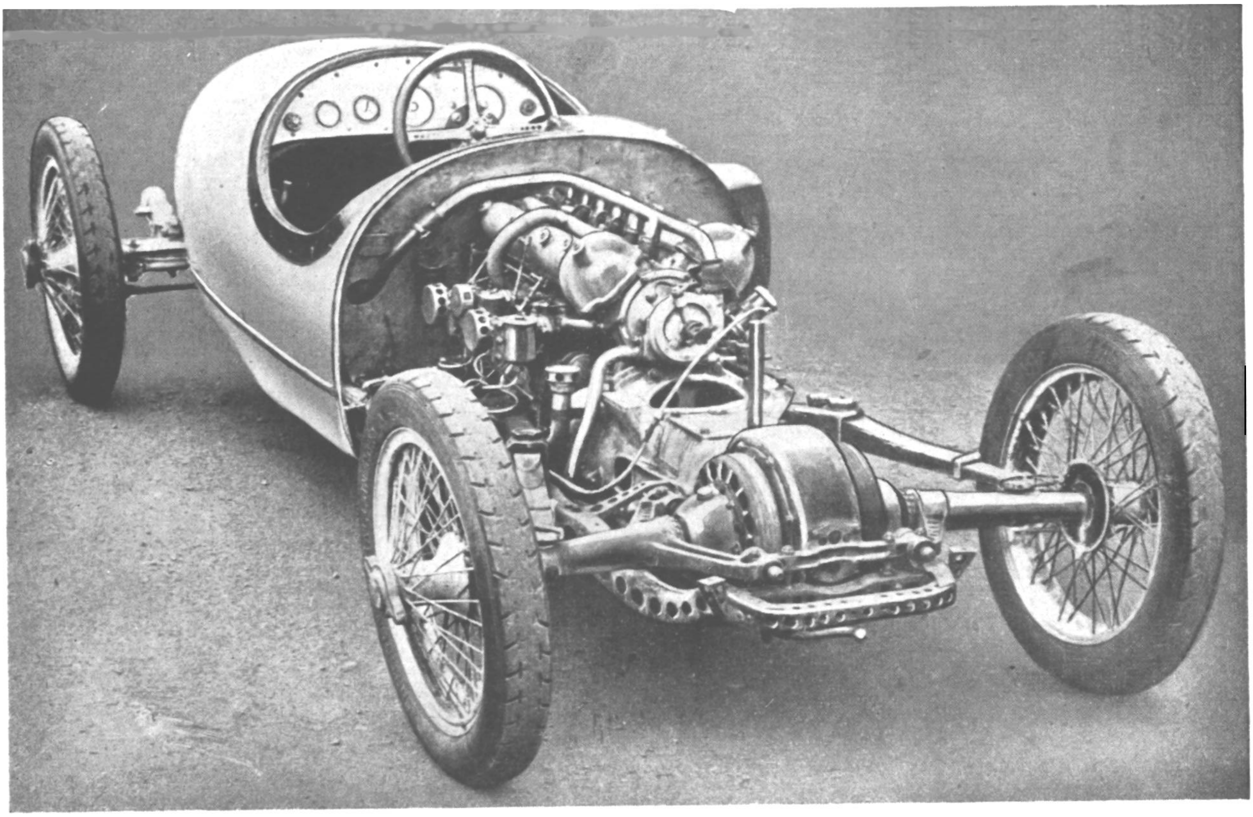
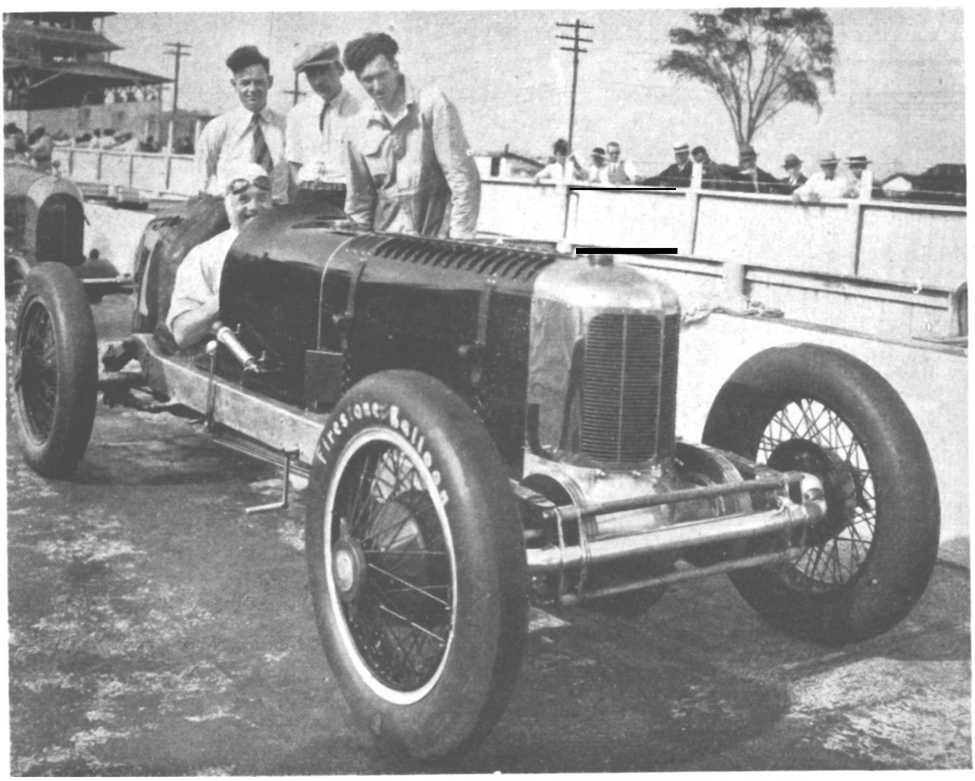


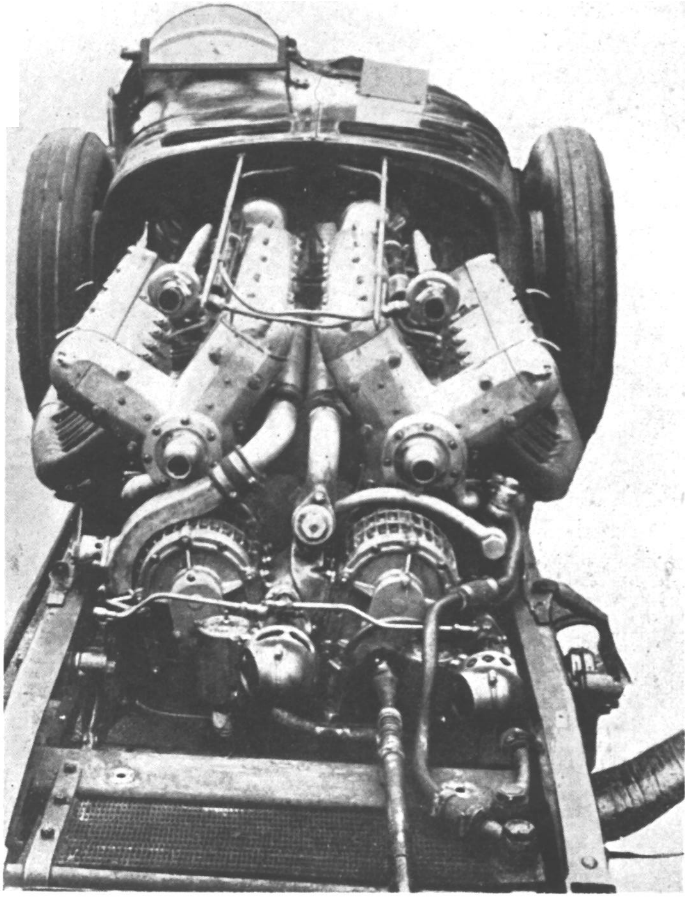
PLATE XXXIX

REAR-END FORECAST - In 1923 the Benz Company built a six-cylinder, 2-litre car to the designs of Professor Rumpler. This was the first rear-engined road racing car and also pioneered the use of independent rear suspension on the swing axle system, as shown in the above photograph.

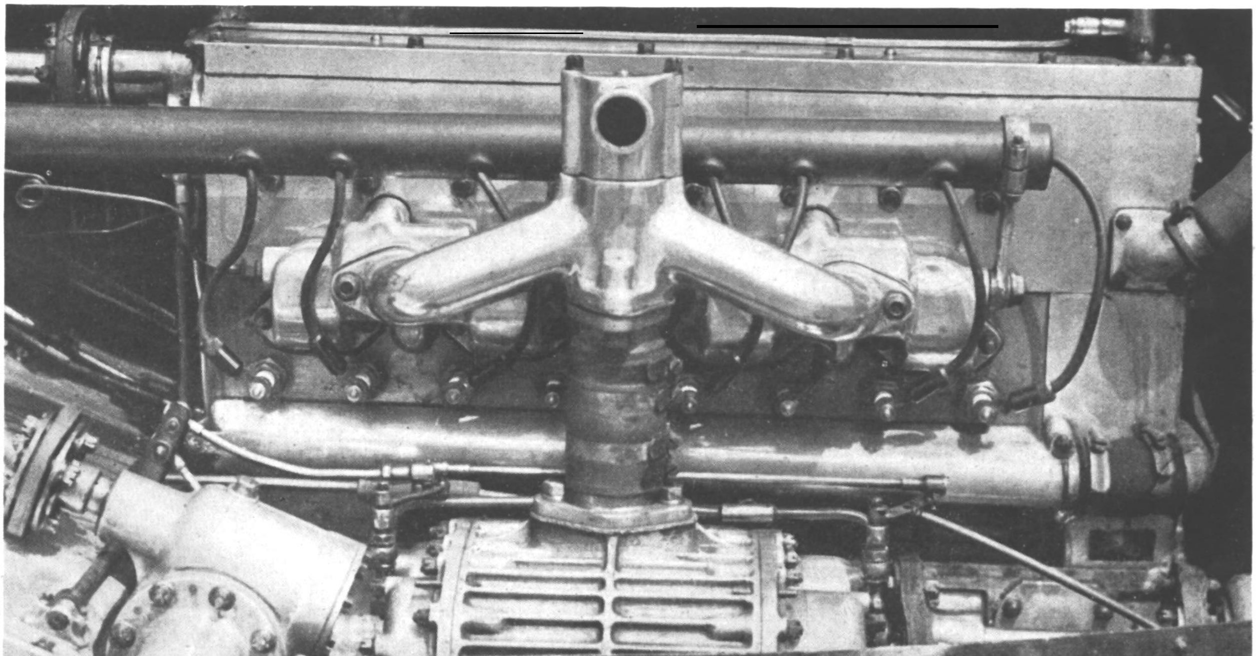


FRONT TO BACK - In 1925 Miller, in America, used the De Dion axle arrangement for the front end of his front-wheel drive Indianapolis cars, a 1926 version of which is shown in this picture. In 1931 the same arrangement was adapted for use on a rear-drive Miller which thus hecame the first racing car to have a De Dion type rear axle.

PLATE XL

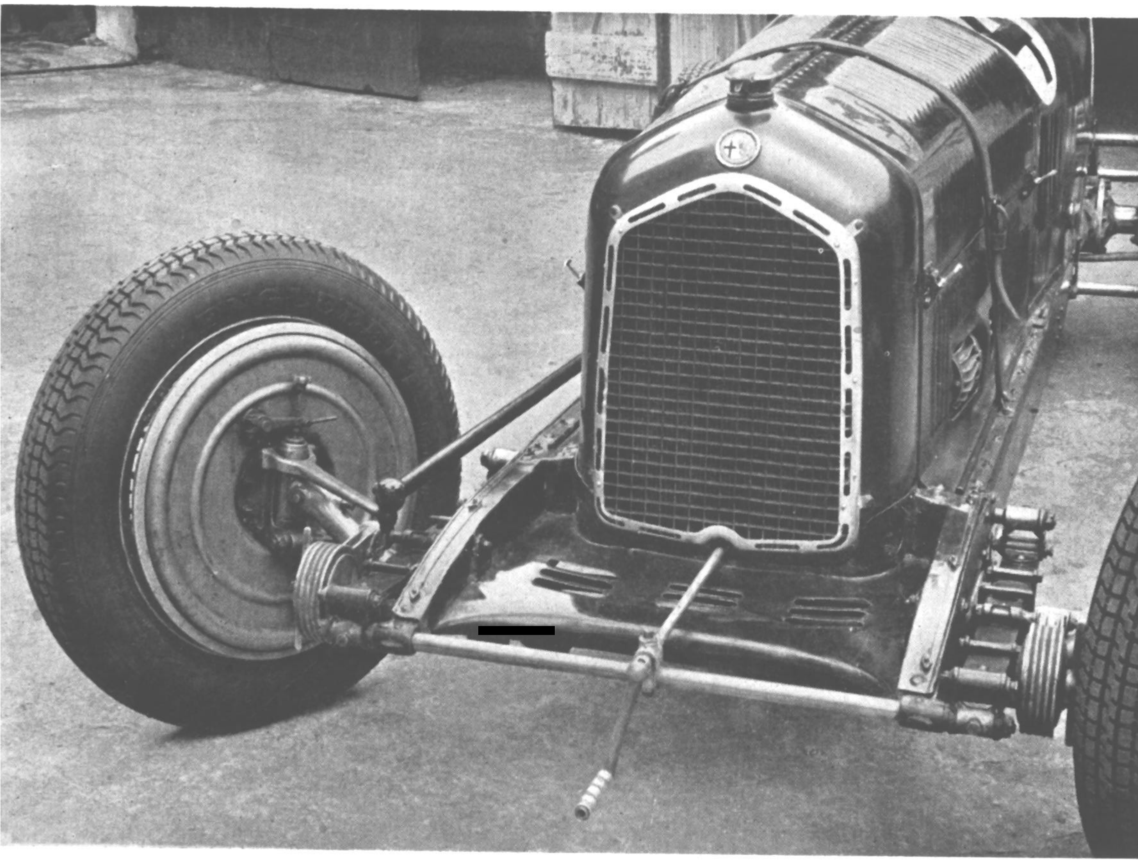


OVER POWERED - In 1929 Maserati built a twin-engine racing car using two supercharged eight-cylinder blocks each of 2 litres capacity and thus produced a car with a sixteen-cylinder, 4-litre, engine developing approximately 300 b.h.p. Although timed on the road at over 152 m.p.h. this car was not successful in normal road racing.

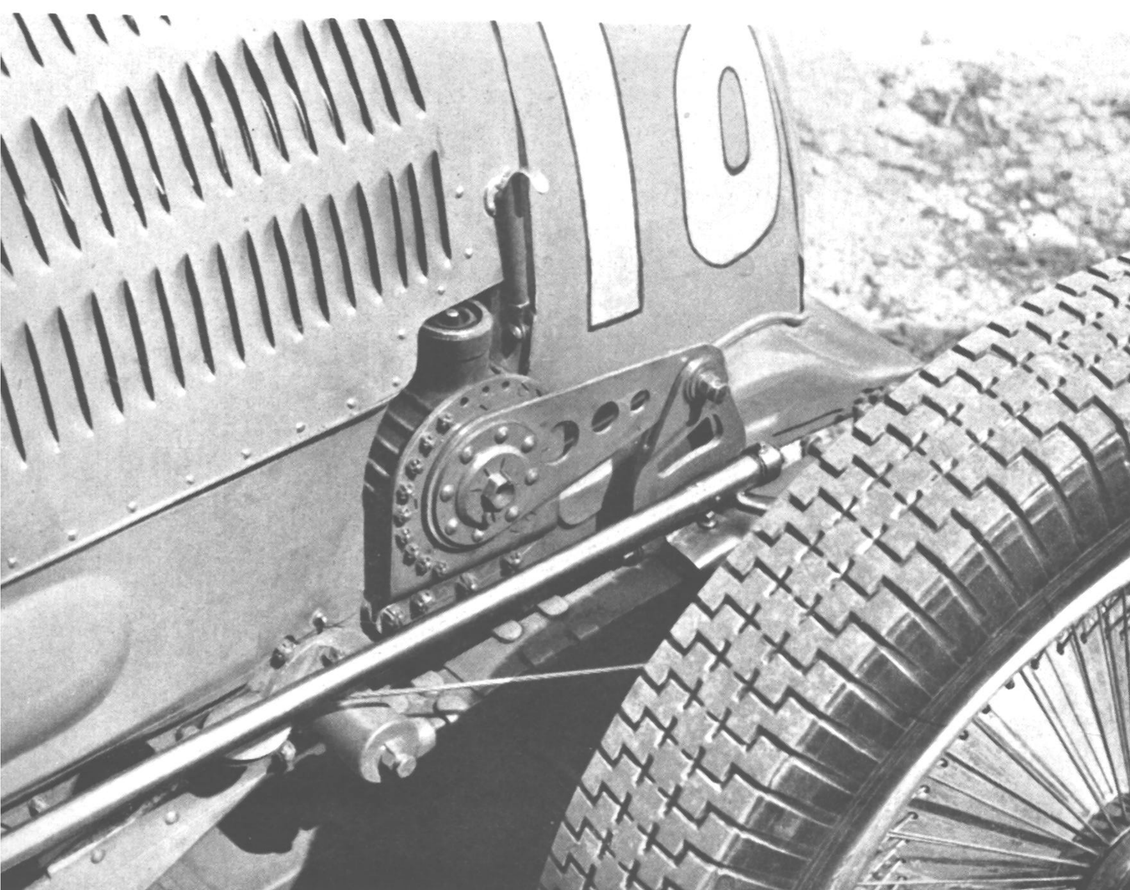


BALANCED QUALITY - The Type 35 Bugatti was by far the most successful racing car judged by sheer number of wins. The straight-eight engine had two cast iron blocks, four cylinders in each, with a single overhead camshaft driven by bevel gears at the front end of the engine. This pjcture also shows the central mounted Roots blower which gave approximately 10 lb. boost, the engine developing approx - imately 135 b.h.p.

PLATE XLI

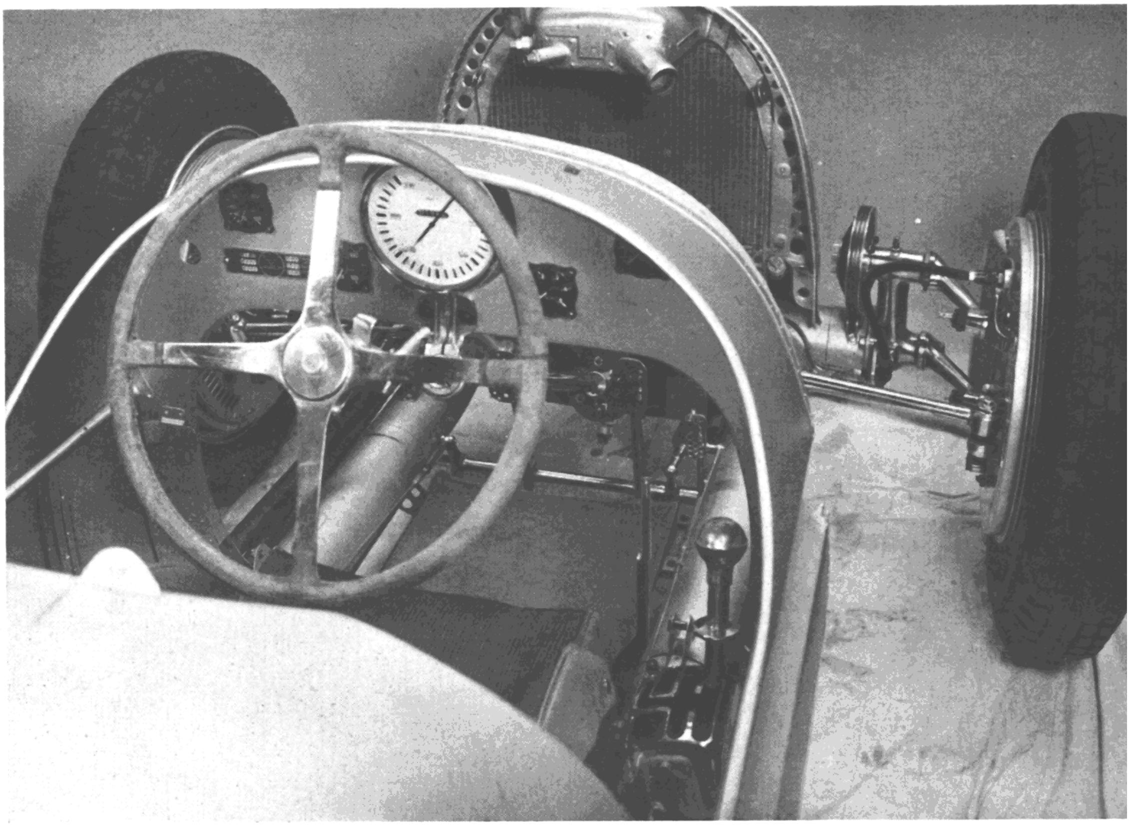


END POINT — The Alf'a Romeo and Bugatti cars produced, between 1932 and 1934, the highest standards of road worthiness achieved by any cars with rigid axles and leaf springs. This photograph shows the out-rigged front springs and comparatively wide track of the 1932 P3 Alfa Romeo, whilst at the back one can see the out-riggers for the widely spaced, rear springs ; also part of one of the twin bevel housings which join the triangular drive embodying double propeller shafts. The low frontal area and clean lines are also well exemplified.



DETAILED REFINEMENTS - The 1938 3-litre Bugatti retained semi - elliptic front springs but these were freed from brake torque by a radius arm connecting to the De Ram shock absorber which combined friction damping with hydraulic loading of the surfaces. This picture also shows the specially designed Bugatti wheel which replaced the cast light alloy type used in previous years.

SIMPLICITY -
In 1934 independent front suspension was first used in Grand Prix racing. The Auto-Union car designed by Dr. F. Porsche used his patented suspension layout in which the wheel was supported through spherical joints on two trailing arms. The bottom arm of each wheel was connected to a torsion bar concealed in the front cross member and running the full width of the car, there being a slight offset so that the bars could be staggered one to the other. The centrally mounted steering box made possible by the rear engine location led to a simple, divided, track rod. Other features made clear by this drawing are the tubular frame and forward mounting of the radiator.



COMPLEXITY -
The 1934/6 Mercedes-Benz 750 kg. formula had independent suspension to the front wheels in which coil springs were concealed in the front cross member. These were actuated by a bell crank and the wheels located by short wishbones of approximately equal length. The relatively complex steering link layout imposed by the front engine mounting is also shown in this picture.

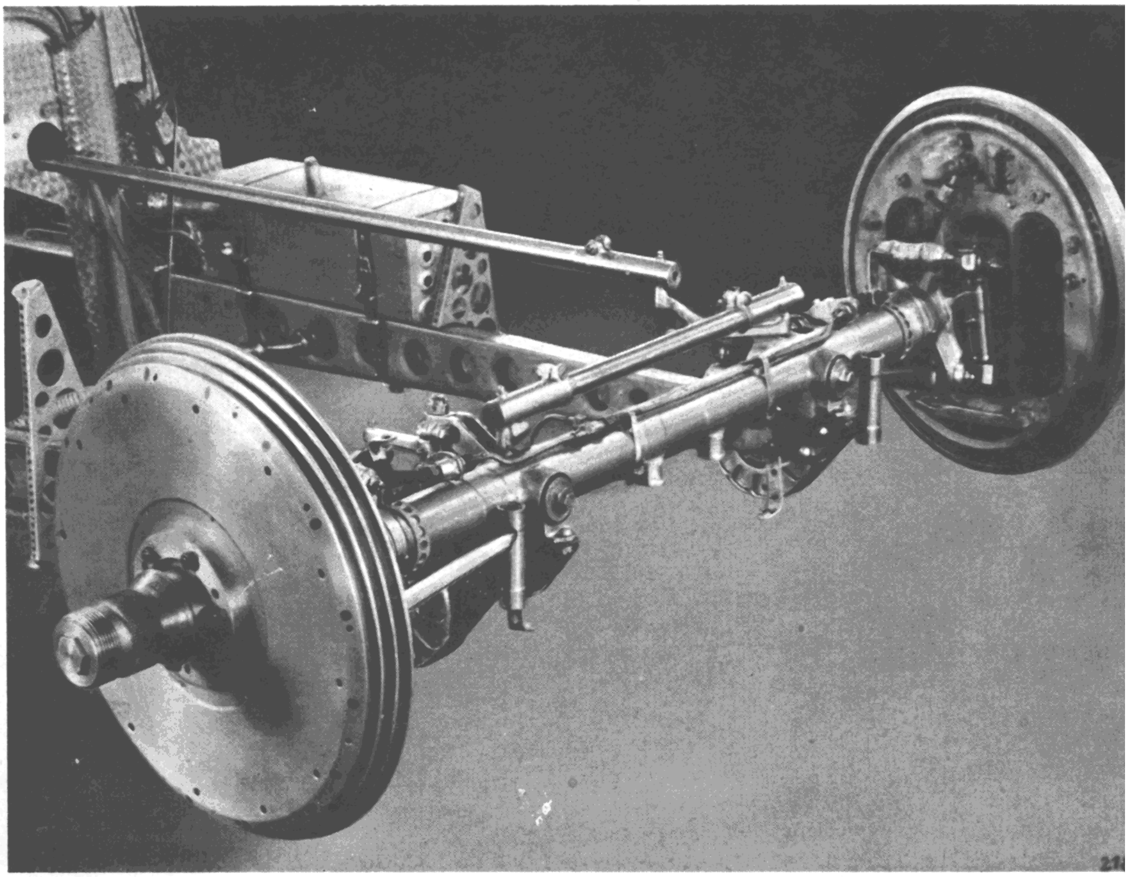
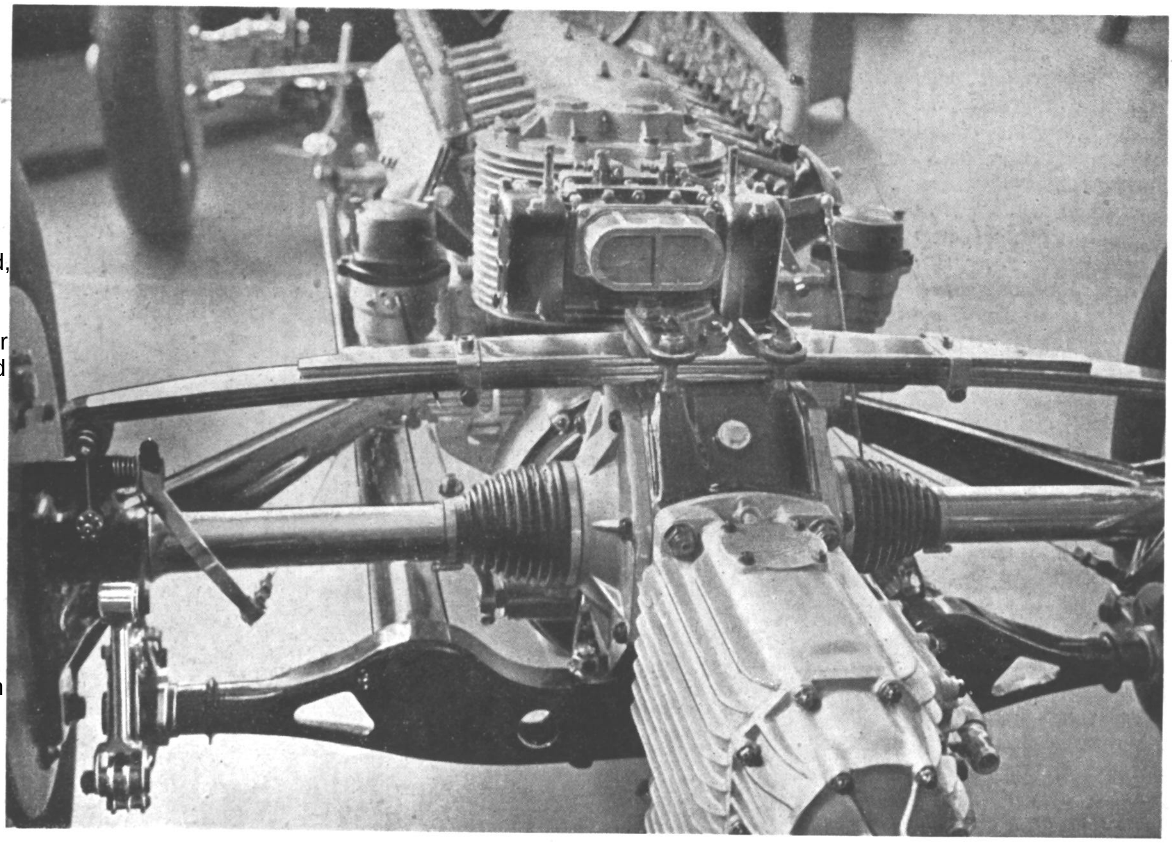
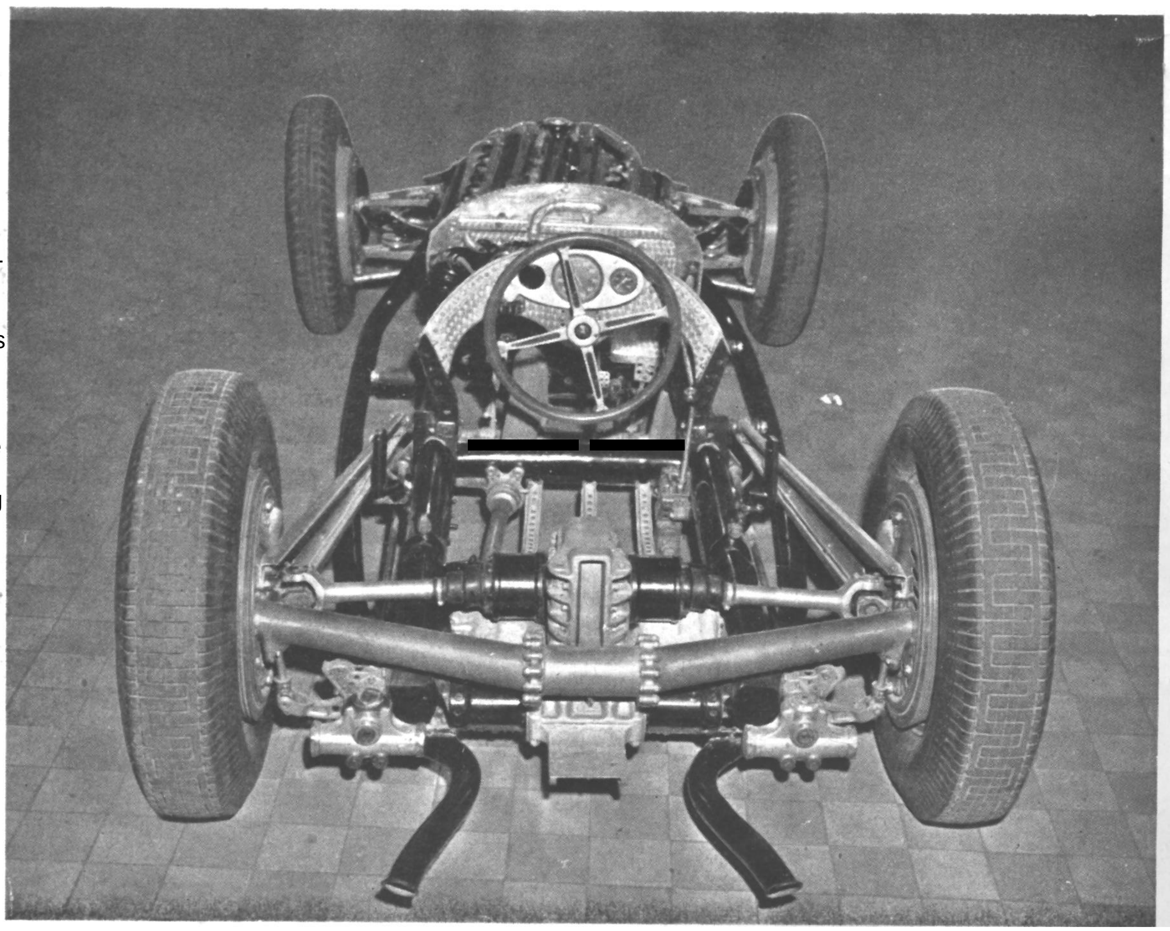


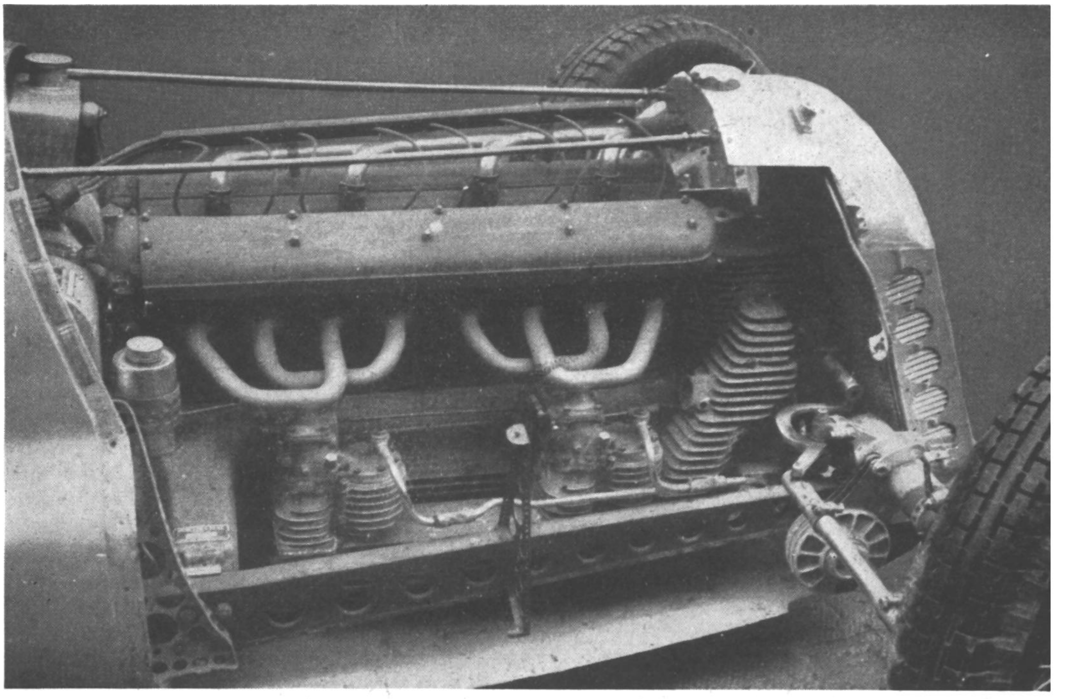
PLATE XLIII



SWING AXLE REVIVAL — Independent suspension for the rear wheels of racing cars was first used on the 1923, rear engined, Benz cars, which employed the swing axle type. Eleven years later this layout was revived by Mercedes-Benz and Auto-Union and the arrangement used on the latter car is shown here. The simple transverse leaf spring was replaced on the 1935/6/7 cars by torsion bars but the basic layout remained unchanqcd with radius arms controlling the movement of each rear wheel.

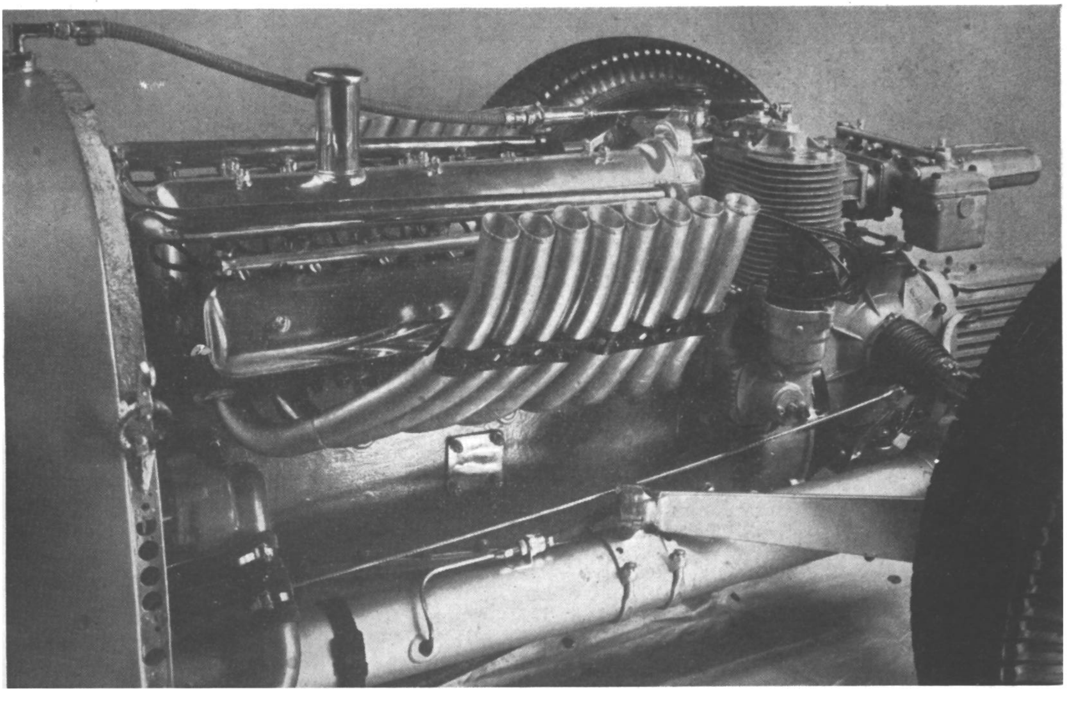


DE DION REVIVAL - The De Dion type of axle was first used in 1894 and was revived for road racing by Mercedes - Benz in 1937, the same components being used during 1938 and 1939. This photograph shows the 1938, 3-litre, car, the cross tube (which is split internally and located sideways in the vertical slot shown in the bevel housing) being a prominent feature. On each side of the car is a radius arm. The drive being taken independently to each wheel through exposed half-shafts with two universal joints on each side. This illustration also shows clearly the marked offset of the propeller shaft and the deep oval tube frame.

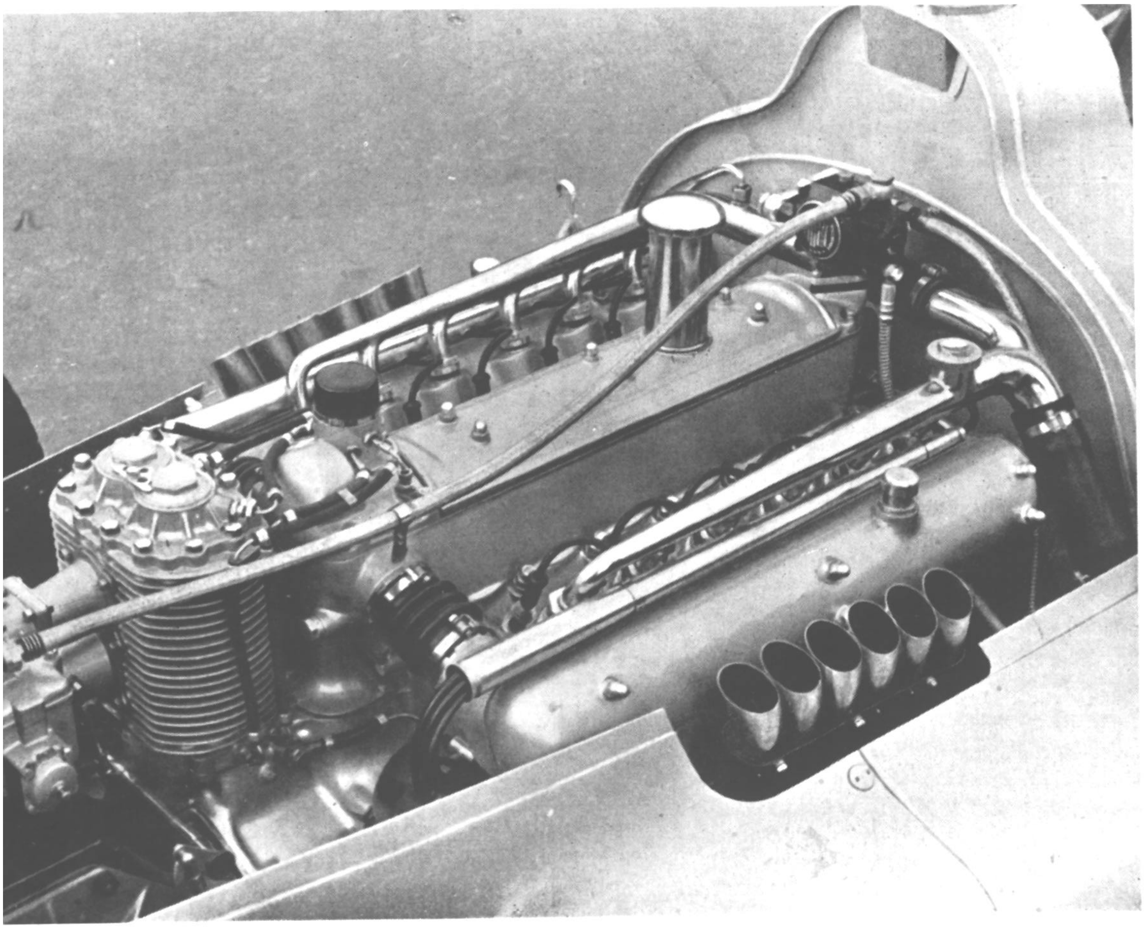


LIGHTWEIGHT CONSTRUCTION - The Mercedes-Benz M.25 series of engines built between 1934 and 1936 varied between 3.36 litres and 4.14 litres capacity with a weight of between 449 and 465 lb. and an output varying between 345 and 494 b.h.p. This illustration shows the 1935 version with bore and stroke 82 mm. by 94.5 mm. (3.99 litres) having an output of 430 b.h.p. at 5,800 r.p.m. The ribbed pipe feeding pressure air to the carburetters should be noted, also the spill valve on the vertical pipe which controlled the inlet manifold pressure.

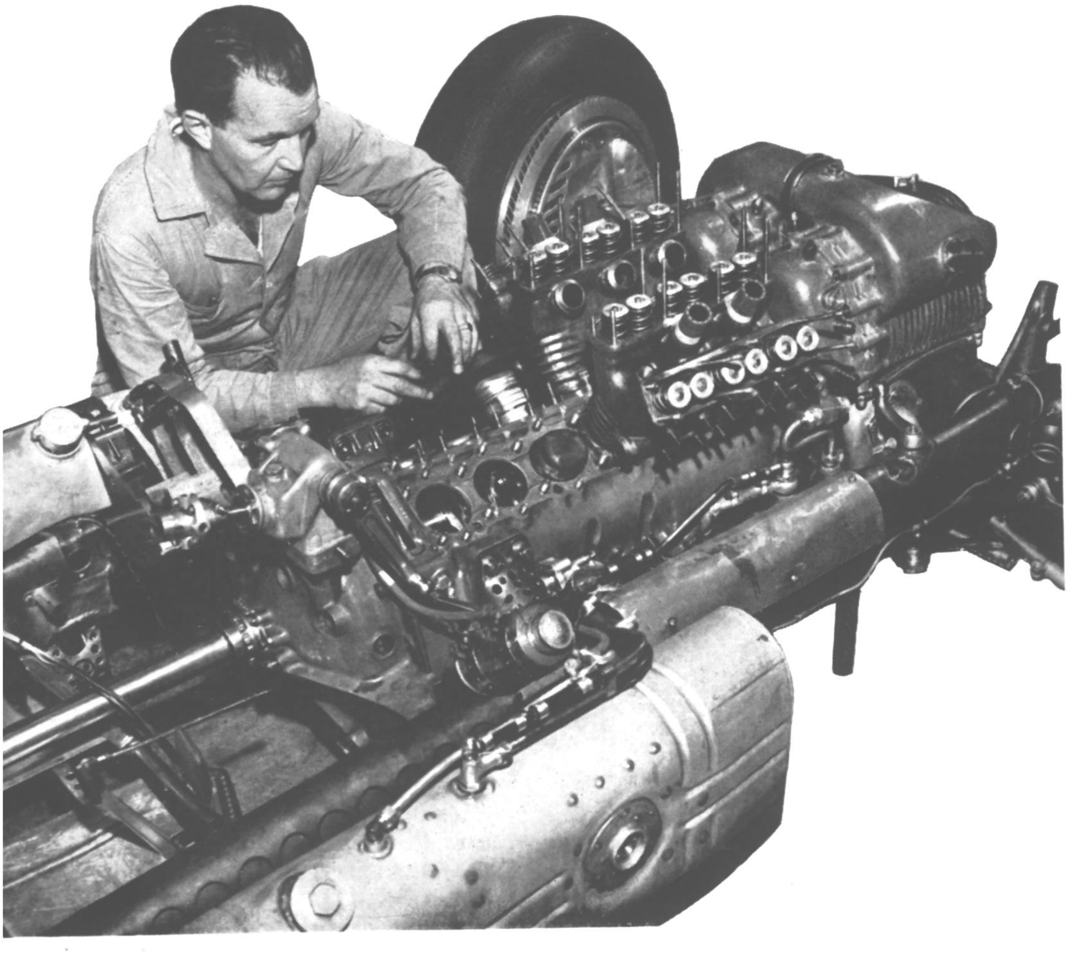
PLATE XLIV



UNIQUE ARRANGEMENT - The 1934/1937 Auto-Union engines were unique in combining rear mounting with sixteen cylinders in Vee formation, the mixture being fed into a central manifold from a supercharger mounted just ahead of the rear axle as shown in this illustration. The picture also shows the water pipe connecting to the forward mounted radiator and the vertically-rising grouped exhaust pipes used from 1935 onwards.



NEAT LAYOUT — The 3-litre Auto-Unions built for 1938/9 were designed by Dr. Werner. The cylinder ases were inclined at 60 degrees and each detachable head carried an exhaust camshaft driven by a short cross-shaft engaging with a vertical drive at the back qf the engine. A single, central camshaft operated all the inlet valves and ran in the same casting used for the inlet manifold. This connected at the back of the engine to a Roots type blower drawing mixture through multiple Solex carhuretters. In 1939 two Roots blowers operated in series drew mixture from floatless D.U.M. carburetters and in this guise the engine gave approximately 500 b.h.p.



CHARACTERISTIC CONSTRUCTIO N — From 1914 onwards all Mercedes-Benz racing cars used forged steel cylinders with integral heads carrying four valves, the ports and water jackets being welded on. The layout of the 1939 V12, 3-litre,engine is shown here. The picture also gives a clear view of the turbine-like fins which shrouded the brake drum and which promoted cooling by a positive air blast. The Roots supercharger seen on the right-hand side of the car is the first-stage delivery being made through the cast pipe into a second, smaller blower, on the left-hand side, the inlet manifold running between the V of the cylinder block.

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THE

GRAND PRIX CAR

by

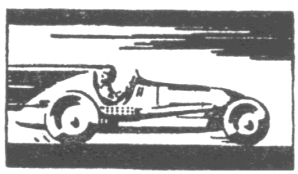
LAURENCE POMEROY

F.R.S.A., M.S.A.E.

Illustrated by

L. C. CRESSWELL

VOLUME TWO



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The Motor

FOREWORD TO VOLUME TWO

THE first volume of the Second Edition of THE GRAND PRIX CAR set out the story of the major road races held before World War II and described in detail seventeen of the typical racing cars which were engaged successfully between 1908 and 1939. It can thus be regarded as a homogeneous work covering a period in which engines were produced giving more power than anything which has since been known, and wherein cars were designed capable of circuit speeds which have been equalled but recently.

Moreover, it was possible to give detail and perspective to both the cars, and to the races in which they ran, for the written matter concerning them was put on paper some ten years after the most recent of them had left the drawing-board to be tried on the track.

Since then a further six years have gone by, and a man who saw the 1939 cars in action, just before he came of age, is now nearer forty than thirty. It is all too easy to echo the cry

> "Eheu ! fugaces, Postume, Postume,
> Labuntur Anni . . ."

and the rest of these melancholy lines. But it is more profitable to evaluate the present in relation to the past and this is the task that I have set myself in this second volume of the Second Edition of THE GRAND PRIX CAR.

It has been possible to assess something of the significance of the very latest 1954 models and to describe and analyse all the cars which have been prominent in post-war racing run under Formulae I and II. A number of descriptions of the races themselves have also been included but the opening section dealing with post-war racing need not be, and the technical descriptions of post-war cars cannot be, on the scale set out in the first volume.

Detailed descriptions of races held between 1947 and 1954 would be redundant as there are a number of books and annuals in which the complete results have been set forth and the races themselves described. So far as the cars are concerned, we stand too close to present events accurately to weigh varying techniques, and in the case of the most successful cars of most recent dates the constructors are naturally reluctant to have full details revealed to possible rivals.

But whereas in Volume One a few typical cars were described in great detail, in the post-war period I have been able to describe all the principal participating models in some detail ; and the reader may think that this change of emphasis is not without some worth of its own.

The story of how the performance of Grand Prix cars has varied from the earliest times up to the end of 1953 has been segregated from the main text in an effort to show how an average speed index based on the 1906 Grand Prix Renault can be set up for all subsequent cars as a consequence of a continuing system of statistical analysis.

This wider view brings us to the second section of the book in which analysis is changed to synthesis, and the emphasis is placed not so much upon " know-how " as " know-why " Much of the material in this section has appeared already in the First Edition of THE GRAND PRIX CAR, but the opportunity has been taken to revise and correct much of the text, considerably to extend certain historic details, notably in respect of early supercharging experiments, and to include a number of hitherto unpublished illustrations. In concluding this section an attempt has been made to bring the technical story of the Grand Prix car right up to date, so that taking the work as a whole there is a complete narrative covering engineering developments for over fifty years.

The first and second volumes are complementary one with another, and indeed, Chapter VI, dealing with average speed indices (which is in any event somewhat hard reading), may be found almost unintelligible by any reader of this volume who is not familiar with the previously published data.*

Nevertheless it is this chapter which contains the root of the whole matter. The Victorian idea of steady progress has, in recent times, been set aside for the more traditional view expressed by Horace in the words (Sir Edward Marsh's translation) :

" Evil our grandsires were, our fathers worse ;
And we, till now unmatched in ill,
Must leave successors more corrupted still."

But this is certainly not so in the world of motor racing. The cars in current competition are as fast as, or even faster, than any previously built ; the courage of their conductors equal to anything displayed in earlier ages, and the sheer technical skill of the first half-dozen drivers at a higher level than anything achieved by earlier generations.

To conclude, I would like to thank all those who gave assistance in the preparation of the first volume equally for their great help in providing information for the second. To their names I would add those of Professor Dr. Ing. R. Eberan von Eberhorst for information concerning the Porsche-designed Cisitalia, Dipl.Ing. Aurelio Lampredi for providing information about the various Ferrari models, and also Mr. G. A. Vandervell who made it possible fully to describe the twelve-cylinder 4½-litre model. Mr. A. G. B. Owen and Messrs. Mays and Berthon have given all possible assistance in connection with the technical details of the B.R.M. and the descriptions of the other cars have also been reinforced by the kind co-operation of the directors and engineers concerned. The author would finally like to give his thanks to the Directors of Temple Press, Limited, without whose assistance and forbearance the whole work could never have been put before the public.

LAURENCE POMEROY, F.R.S.A., M.S.A.E.

London
October, 1954

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* Volume One was published in February, 1954, and the text of 247 pages is in two parts. The first of these surveys motor racing from 1894 to 1939, in fourteen chapters, wherein are described 235 races, with tables, giving the winner and holder of record lap with respective speeds. Then, in Part Two, follow detail descriptions, fully illustrated, of seventeen typical Grand Prix cars : 1908 Itala 12-litre ; 1911 Fiat 10-litre ; 1912 Peugeot 5.6-litre ; 1913 Peugeot 3-litre ; 1914 Mercedes 4-litre ; 1920 Ballot 3-litre ; 1922 Vauxhall 3-litre ; 1922 Fiat 2-litre ; 1924 Sunbeam 2-litre ; 1927 Delage 1.5-litre ; 1926 Bugatti 2.3-litre ; 1930 Bentley 4.5-litre ; 1932 Alfa Romeo 2.65-litre ; 1934 Mercedes-Benz 4-litre ; 1936 Auto Union 6-litre ; 1937 Mercedes-Benz 5.66-litre and 1939 Mercedes-Benz 3-litre. In an appendix the results and lap speeds of 200 major races from 1906 to 1939 are tabulated.

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ILLUSTRATION ACKNOWLEDGEMENTS

The Author wishes to acknowledge the valuable assistance received in the provision of illustrations and to thank in particular Jerry Cheseborough (Plates VIII, IX), Corrado Millanta (Plates XII, XIII, XVIII, XIX), Count G. Lurani (Plate XXII), P. C. Kidner, Esq. (Plate XXXII), and L. Klementaski, Esq. (Plate XLIII). The scale drawings of the B.R.M. and Ferrari Formula I and Formula II models were kindly supplied by Rex Hays, Esq.

ILLUSTRATIONS

ILLUSTRATIONS-Continued

GRAPHS

Part Three

RESTORING THE *STATUS QUO ANTE-BELLUM*

A Summary of Racing under Formulae I and II, and a description of the competing Grand Prix Cars of 1947-53

" Men's minds indeed conceive new thoughts and plan new projects, but out of ancient thinking, under the potent influence of long-established characteristics."

THE TIMES LIT. SUPP.

" . . . nothing is so hard, as to give wise council before events ; and nothing so easie as, after them, to make wise reflections. Many things seem true in reason. and prove false in experience : many, that are weakly consulted, are executed with success."

SIR WILLIAM TEMPLE.

CHAPTER ONE

The March of Events

FORMULA I - STATISTICS FOR MAJOR RACES, 1947-51

Date	*Event*	*Circuit*	*Driver*	*Car*	*Winning Speed (m.p.h.)*	*Best Lap (m.p.h.) (Rec'd*)*
7/7/47	Pau G.P.	Pau	N. Pagani	Maserati	51.95	55.5
8/5/47	J.C.C.	Jersey	R. Parnell R. Sommer	Maserati Maserati	84.52 —	— 91.28*
8/6/47	Swiss G.P.	Berne	J.-P. Wimille	Alfa Romeo	95.42	96.85
29/6/47	Belgian G.P.	Spa	J.-P. Wimille	Alfa Romeo	95.28	101.94
6/7/47	Marne G.P.	Rheims	C. Kautz L. Villoresi	Maserati Maserati	95.8 —	— 100.99
13/7/47	G.P. d'Albigeois	Albi	L. Rosier L. Villoresi	Talbot Maserati	88.41 —	— 98.2
13/7/47	Bari G.P.	Lungomare	A. Varzi	Alfa Romeo	65.1	70.68*
7/9/47	Italian G.P.	Turin	C. Trossi	Alfa Romeo	70.29	74.16
21/9/47	G.P. de 1'A.C.F.	Lyons	L. Chiron Villoresi, Ascari, de Graffenried	Talbot Maseratis	78.09 —	— 82.4*
12/10/47	Turin G.P.	Turin	R. Sommer	Ferrari	67.5	69.88*
29/3/48	Pau G.P.	Pau	N. Pagani J.-P. Wimille	Maserati Simca	53.07 —	— 56.29
29/4/48	J.C.C.	Jersey	F. R. Gerard	E.R.A.	87.33	90.42
30/4/48	G.P. des Nations	Geneva	G. Farina	Maserati	61.38	63.86*
16/5/48	Monaco G.P.	Monte Carlo	G. Farina	Maserati	59.61	62.32
27/6/48	San Remo	San Remo	A. Ascari	Maserati	57.66	—
4/7/48	G.P. de l'Europe	Berne	C. F. Trossi J.-P. Wimille	Alfa Romeo Alfa Romeo	90.81 —	 95.05
18/7/48	G.P. de 1'A.C.F.	Rheims	J.-P. Wimille	Alfa Romeo	102.1	108.14 112.2 (P)
29/8/48	G.P. d'Albigeois	Albi	L. Villoresi	Maserati	99.88	104.42*
5/9/48	Italian G.P.	Turin	J.-P. Wimille	Alfa Romeo	70.38	78.61 (P)
2/10/48	R.A.C. G.P.	Silverstone with chicanes	L. Villoresi	Maserati	72.28	76.82*

Formula I-Statistics for Major Races, 1947-51 (continued)

7/10/48	Monza G.P.	Monza	J.-P. Wimille C. Sanesi	Alfa Romeo Alfa Romeo	109.98 —	 116.95*
1/10/48	Penya Rhin	Pedralbes	L. Villoresi	Maserati	89.44	94.16*
3/4/49	San Remo G.P.	San Remo	J. M. Fangio B. Bira	Maserati Maserati	62.87 —	— 64.66*
28/4/49	B.A.R.C.	Jersey	F. R. Gerard L. Villoresi	E.R.A. Maserati	77.1 —	— 90.0
14/5/49	British G.P.	Silverstone with chicane	de Graffenried B. Bira	Maserati Maserati	77.31 —	— 82.82
18/5/49	Pau G.P.	Pau	J. M. Fangio	Maserati	52.7	56.85
19/6/49	Belgian G.P.	Spa	L. Rosier G. Farina	Talbot Maserati	96.95 —	— 101.64
3/7/49	Swiss G.P.	Berne	A. Ascari G. Farina	Ferrari Maserati	90.76 —	— 95.1
10/7/49	G.P. d'Albigeois	Albi	J. M. Fangio	Maserati	98.19	102.17
17/7/49	G.P. de France	Rheims	L. Chiron P. Whitehead	Talbot Ferrari	99.98 —	— 105.1
31/7/49	Zandvoort G.P.	Zandvoort	L. Villoresi B. Bira	Ferrari Maserati	77.12 —	— 79.49*
20/8/49	International Trophy	Silverstone perimeter	A. Ascari	Ferrari	89.58	93.35*
11/9/49	G.P. d'Europe	Monza	A. Ascari	Ferrari	105.04	112.72(P)
10/4/50	Pau G.P.	Pau	J. M. Fangio	Maserati	58.4	60.28*
16/4/50	San Remo	San Remo	J. M. Fangio L. Villoresi	Alfa Romeo Ferrari	59.65	— 62.3
13/5/50	G.P. de 1'Europe	Silverstone	G. Farina	Alfa Romeo	90.95	94.02*
21/5/50	Monaco G.P.	Monte Carlo	J. M. Fangio	Alfa Romeo	61.33	64.09
4/6/50	Swiss G.P.	Berne	G. Farina	Alfa Romeo	92.76	100.78
18/6/50	Belgian G.P.	Short Spa	J. M. Fangio G. Farina	Alfa Romeo Alfa Romeo	110.05 —	— 115.15
2/7/50	A.C.F. G.P.	Rheims	J. M. Fangio	Alfa Romeo	104.83	112.35 116.2 (P)
9/7/50	Bari	Lungomare	G. Farina	Alfa Romeo	77.31	81.28
13/7/50	B.A.R.C.	Jersey	P. Whitehead D. Hampshire	Ferrari Maserati	90.94 —	— 94.43*
15/7/50	Circuit of Pescara	Pescara	J. M. Fangio	Alfa Romeo	83.95	90.33
17/7/50	Albi G.P.	Albi	L. Rosier J. M. Fangio	Talbot Maserati	— —	— 106.63*
23/7/50	Netherlands G.P.	Zandvoort	L. Rosier J. M. Fangio	Talbot Maserati	76.44 —	— 83.5*

Formula I-Statistics for Major Races, 1947-51 (continued)

30/7/50	G.P. des Nations	Geneva	J. M. Fangio P. Taruffi	Alfa Romeo Alfa Romeo	79.74 —	85.63*
26/8/50	International Trophy	Silverstone	G. Farina	Alfa Romeo	90.16	92.85
3/9/50	Italian G.P.	Monza	G. Farina J. M. Fangio	Alfa Romeo Alfa Romeo	109.67 —	— 117.44*
29/10/50	Penya Rhin	Pedralbes	A. Ascari	Ferrari	93.8	97.7*
26/3/51	Pau G.P.	Pau	L. Villoresi A. Ascari	Ferrari Ferrari	57.32 —	60.15
22/4/51	San Remo	San Remo	A. Ascari	Ferrari	63.9	66.28*
27/5/51	Swiss G.P.	Berne	J. M. Fangio	Alfa Romeo	89.05	104.46(P)
17/6/51	Belgian G.P.	Short Spa	G. Farina J. M. Fangio	Alfa Romeo Alfa Romeo	114.26 —	— 120.51*
1/7/51	A.C.F. G.P.	Rheims	J. M. Fangio	Alfa Romeo	110.97	118.29* 119.99(P)
14/7/51	British G.P.	Silverstone	F. Gonzales G. Farina	Ferrari Alfa Romeo	96.11 —	100.65(P) 99.9*
22/7/51	Netherlands G.P.	Zandvoort	L. Rosier A. Pilette	Talbot Talbot	78.46 —	— 82.27
29/7/51	German G.P.	Nürburg	A. Ascari J. M. Fangio	Ferrari Alfa Romeo	83.76 —	— 85.69
20/5/51	Paris G.P.	Bagatelle	G. Farina J. M. Fangio	Maserati Simca	67.3 —	70.97
2/6/51	Ulster Trophy	Dundrod	G. Farina	Alfa Romeo	91.4	94.0*
5/8/51	Albi G.P.	Albi	M. Trintignant	Simca	100.2	104.53
16/8/51	Pescara	Pescara	F. Gonzales	Ferrari	85.32	88.86
2/9/51	Bari G.P.	Lungomare	J. M. Fangio A. Ascari	Alfa Romeo Ferrari	83.92 —	— 87.89*
16/9/51	Italian G.P.	Monza	A. Ascari G. Farina	Ferrari Alfa Romeo	115.53 —	— 120.97* 124.53(P)
28/10/51	Spanish G.P.	Pedralbes	J. M. Fangio A. Ascari	Alfa Romeo Ferrari	98.76 —	105.2* 108.1(P)

THE first post-war road race to be held in Europe was run on September 9th, 1945, on a 1¾-mile circuit in Bois de Boulogne, just outside Paris, and held under *formule libre* it resulted in a win for a Bugatti, driven by Jean-Pierre Wimille, who averaged 71 m.p.h. over a distance of 70 miles. During 1946 nineteen races were held under various regulations in Europe (starting with the Nice Grand Prix on April 22nd), and one meeting was organised in England jointly by the Cambridge University Automobile Club and the Vintage Sports-Car Club, and another in Northern Ireland

where the Ulster Automobile Club put on a 50-mile road race. It is hard now to recollect the immense dislocation in the immediate post-war period and it is really remarkable that racing should so quickly re-establish itself in the face of great shortage of supplies of fuel, plugs and, more particularly, tyres, and the very difficult communications owing to the damage done to harbours and bridges during the last few months of the war period. The members of the F.I.A. were fully cognisant of these problems when they laid down Formula I and they doubtless had in their minds the fact that there were a number of existing 4½-litre cars which had run unsupercharged in the 1938-9 formula and an even larger number of 1½-litre cars which had competed in voiturette races between 1934 and 1939. They decided, quite rightly, that the conjunction of these two types should, from fundamental considerations, result in very balanced competition. The pool of racing cars which could immediately be drawn upon may be conveniently sub-divided into nationalities as follows :

FRANCE

Delahaye

One single-seater, twelve-cylinder, unsupercharged 4½-litre.

Talbot

Several six-cylinder, 4-litre models with offset single-seater bodies as run at Rheims in 1938 with a lap speed of 98.8 m.p.h. Also one central single-seater using a modified chassis which ran in the 1939 French Grand Prix and lapped the Rheims circuit at 105 m.p.h.

GERMANY

Mercedes-Benz

1½-litre V.8, Type W165. These were not available for use by the company as a consequence of their having been interned in Switzerland during the war years.

GREAT BRITAIN

Alta

1½-litre, four-cylinder, designed in 1939 with all-independent wheel suspension and tubular frame.

E.R.A.

A, B and C Types (1934-7), six-cylinder, 1½-litre with Roots supercharger on A and B Type chassis having rigid front axle ; and Zoller compressor on C Type fitted with trailing arm i.f.s.

E Type (1939) six-cylinder with larger piston area and shorter stroke, Zoller supercharged, engine installed in tubular frame with trailing arm front suspension and de Dion rear axle.

ITALY

Alfa Romeo

Eight-cylinder, in-line, 1½-litre cars with single Roots blowers, trailing arm front suspension, tubular frames, and swing axle rear suspension. These cars had been designed in 1937 and had run with great success in the 1½-litre races of

1938-9. They had continued to race during 1940 and had won the Tripoli Grand Prix in that year at a speed higher than that achieved by the l½-litre Mercedes-Benz cars which had defeated them in the previous year.

Maserati

Represented by a number of four- and six-cylinder, l½-litre cars dating back to 1934 but primarily by the Type 4 CL which appeared in 1939. This had a four-cylinder engine with a single Roots blower, independent front suspension with wishbones connected to torsion bars and normal live axle attached to the frame by quarter-elliptic springs. The channel-type frame was cross-braced by a cast light-alloy oil tank placed beneath the driving seat.

The specifications of these cars are considered in more detail in subsequent Chapters, but the foregoing will suffice to put the reader in the picture for the brief survey of the immediate post-war racing which is about to be set down.

In the first year of Formula I Maserati won the first race to be organised, which was at Nice, and this was a prelude to a very happy year for them in which they won no fewer than six major events.

Talbot were the third most successful car from a statistical point of view and whereas Maserati did not win any of the Grandes Epreuves, Talbot were both first and third in the French Grand Prix.

It is worth recording that if we except 1936 and 1937, when the Grand Prix de 1'A.C.F. was run under sports-car regulations, this was the first time the event had been won by an unsupercharged car since 1923 and it was the first Grande Epreuve of any kind to be won by an unsupercharged car since the 1925 Targa Florio.

It is only fair to add that Alfa Romeo were not competing in the French event of 1947, and that they were unbeatable in the Grandes Epreuves organised by the Swiss, Belgian and Italian National Clubs, and in fact occupied the first three positions in all three of them. The overwhelming supremacy of these cars (which now bore the designation Type 158) was due in part to modifications to the induction system in the shape of two-stage blowing which made its first appearance on the cars which ran in the Grand Prix des Nations at Geneva, in July, 1946. This had the effect of raising the output to 254 b.h.p. at 7,500 r.p.m., which compared with 225 h.p. at the same engine speed obtained from the single-stage models at the end of 1939, and 190 b.h.p. at 6,500 r.p.m. which had been realised on the first tests made in 1938. During the course of 1947, the engine speed remained at 7,500 r.p.m. but output was raised to 265 h.p. Although Alfa Romeo came second on the list of wins (and equally second on a points system which gives 5 points for a first, 3 for a second, and 1 for a third place), there is no question that they were the finest racing cars of the year.

The racing record by makes for all the Formula I races held until the end of 1951 is set out in tabular form, and reference to this table will show that no make other than those mentioned above secured a win in Formula I racing in 1947. A summary of the year should, however, not be concluded without reference to a matter of historic importance. This was the appearance in racing (although not in Formula I) of a new make : Ferrari.

Enzo Ferrari had, for many years, run a team of Alfa Romeo cars as a private venture (the Scuderia Ferrari), and the l½-litre Alfa Romeo models had, in fact, been

designed at his request, the engine tested in his workshops at Modena, and the cars raced by his organisation in the pre-war years. Moreover, his new car was designed by an ex-Alfa Romeo engineer, Colombo, who had been closely associated with the Type 158. As built in 1947 and raced at Modena and Turin, the car took the form of a 2-litre sports-model fitted with a V.12-cylinder engine fitted into a tubular chassis having independent front suspension using a transverse leaf and normal live rear-axle.

Of the British cars, only the E.R.A. B Type was successful during 1947 (with two third places), although both Alta and all the various types of E.R.A. appeared on the entry lists. Unfortunately, only the E Type with high supercharge pressure could offer performance equivalent to the leading Continental cars and the racing history of this model in 1947 was dogged by an unreliability and misfortune which pursued it until it was withdrawn from active competition in 1949.

In 1948 Alfa Romeo maintained their superiority using a car with the Type No. 158/47 which had been developed during the previous year, but not actually raced therein. The principal difference between this and the preceding model was a larger first-stage blower giving higher supercharge pressure, and during the year the power output was raised to 310 h.p. without changing the peak crankshaft speed of 7,500 r.p.m. The Belgians did not stage a Grande Epreuve and Alfa Romeo did not compete in the revived R.A.C. Grand Prix which, for this year only, was held over a very circuitous aerodrome course. All the other Grandes Epreuves were won by Alfa Romeo, also a race run as the Monza Grand Prix over a reconstructed circuit on this historic site.

Competing in only four races, the Milan firm could not have achieved more than 36 points, and did in fact obtain 31 ; even so this was only half the number secured by Maserati, which continued to be the most successful racing car of the year if one takes all events into consideration. Although not a match for the Alfa Romeo on sheer speed, the Maserati made a considerable step forward when they introduced the Type 4 CLT 48 for the San Remo Grand Prix at the end of June. This, it should be noted, followed the departure of the Maserati brothers themselves from the firm in 1947, leaving it to Signor Orsi, as chief designer, to produce a model with a two-stage supercharged engine with a claimed 240 h.p. installed in a chassis having a tubular frame and independent front suspension with wishbones conjoined to short helical springs working at about 60 degrees from the vertical. The rear suspension elements remained unchanged but the bodywork was improved, the front cowling being very noticeably lower. There were also some internal alterations to the engine.

The works-sponsored San Remo Maseratis driven throughout the year by Alberto Ascari and Luigi Villoresi were beaten only by Alfa Romeo, and Lago Talbot had a somewhat disappointing year despite the introduction of a newly engined car which made its first appearance at Monte Carlo on May 16th and achieved second place therein. In addition to a 4½-litre in place of a 4-litre swept volume, the new power unit had 90-degree valves worked by push-rods and rockers from two camshafts, and three carburetters with an external conduit to their intakes mounted above the bonnet.

Somewhat strangely, the speed of this car on the Rheims circuit was a good deal slower than that of the single camshaft 4-litre of the previous year and the model

compared very unfavourably with the San Remo Type Maserati, which in turn was equally far away from the remarkable speed of the Type 158/47 Alfa Romeo.

Probably the finest demonstration of the potential pace of the latter was seen during practice for the A.C.F. Grand Prix at Rheims when J.-P. Wimille made a special attempt with a cleared course to equal the race lap record put up by the Type W163 Mercedes-Benz in 1939. Although he failed in his endeavour he was undoubtedly driving the car at the highest possible speed at this time, and he was over 11 m.p.h. faster than the best lap put up the previous year on the circuit by the 4 CL Maserati.

There were two other notable features of the 1948 season. One of these was something of a comeback by the B and C Type E.R.A. cars in the hands of private owners. Running with lower boost and Roots-type blowers, these pre-war cars blended speed with reliability in such a manner that they were able to win two of the lesser races and failed by only one mark to finish equally third with Lago Talbot on a points basis. As a presage of the future the arrival of Ferrari in Formula I racing was more important.

Three of these cars made their debut on September 5th at the Italian Grand Prix and they differed from the 2-litre model which ran at the end of 1947 not only by having the engine capacity reduced to 1½ litres, but also by the provision of a single Roots blower, all-independent wheel suspension with swing axle at the rear, and the remarkably short wheelbase of 7 ft. 1 in. The Italian Grand Prix was run in heavy rain and the one Ferrari which finished took third place. In the Monza Grand Prix no Ferrari finished, but the l½-litre car ended the season by taking first and second places at Garda and earlier in the year the unblown 2-litre picked up a third place in Geneva.

By the end of 1948 Alfa Romeo had shown complete superiority over all opposition in three seasons of racing, two of them under Formula I regulations. With this to their credit they decided, for at least twelve months, not to incur the very big expenses involved in a Grand Prix racing season and the Grandes Epreuves in the third year of Formula I were in consequence more closely contested but run at lower speeds. The loss in speed may be best appreciated if set out in tabular form thus :

LAP SPEEDS OF 1949 FORMULA I CARS, cf. 1946-8 Type 158 Alfa Romeo

Cars	*Rheims*	*Berne*	*Monza*
1946-8 Alfa Romeo	112.2	96.85	116.95 m.p.h.
1949 1.5-litre Ferrari	107.9	92.9	112.72 m.p.h.
1949 1.5-litre 4 CLT Maserati	106.7	95.26	110.6 m.p.h.
1949 4.5-litre Talbot	99.98	92.4	104.5 m.p.h.

Some of the lesser Forrnula I races, on the other hand, showed a marked increase in speed, for example, at San Remo the race winning speed of the 4 CLT Maserati, of which this event became the cognomen, rose from 57.66 to 62.87 m.p.h. In the absence of Alfa Romeo this model was certainly the fastest racing car taking the whole range of major international Formula I events into consideration. This notwithstanding, Ferrari can legitimately claim that they stepped into the shoes left vacant by Alfa Romeo so far as the Grandes Epreuves were concerned, for whereas Maserati was victorious in only one race of this calibre Ferrari were first and second ; first and third ; first ; and

second and third in the remaining races of this order. They were additionally third in the Grand Prix de France at Rheims, which was won by a Talbot. This had the moral importance of a Grand Epreuve in that the traditional Grand Prix de l'A.C.F. was run elsewhere as a sports-car event. Only this technicality prevents Talbot from inscribing two French Grand Prix wins on their record and they were also winners of the Belgian Grand Prix and runners-up in the European and Czechoslovakian Grands Prix.

The works-sponsored Talbots of this year were, of course, all of the double-camshaft type with centrally placed single-seater bodies but they were still so much slower than the l½-litre supercharged cars that it seemed most unlikely that atmospheric could ever challenge high density induction within the framework of Formula I.

Undoubtedly the fastest car of the year was a twin-camshaft, two-stage blown Ferrari which made a single appearance at the end of the season (September) to win the European Grand Prix on the Monza circuit.

At this stage the E.R.A.s with six or more racing seasons behind them continued roughly to equal in speed the post-war 4½-litre Talbots, and they kept themselves in the picture not only with two firsts in races which some may consider of only local interest, but also with a well-merited second in a Grande Epreuve.

In 1950 Alfa Romeo received financial assistance which enabled them to return to the field of Formula I racing. As the highest lap speed of the two-stage Ferrari at Monza in 1949 had been 112.72 m.p.h. as compared with the Type 158's 116.95 m.p.h. Alfa Romeo had no hesitation in bringing their now thirteen-year-old design out of storage and embarking on another racing year with it. In order, however, to ward off any surprises which might be sprung upon them by other rivals (including doubtless the British B.R.M., of which much was beginning to be heard) the peak r.p.m. was raised from 7,500 to 8,500 with a corresponding increase in h.p. from 310 to 350 without change of b.m.e.p. Detail changes to the air intake and exhaust manifolds were also made, and it is a striking testimony to the soundness of the original design that these cars were once again able to sweep the board by winning all the Grandes Epreuves and amassing a total of 79 points in the twelve events in which they competed. Moreover, although it cannot be said that they were really hard-pressed until the very end of the season, they consistently broke previous Formula I lap records including a practice lap at 116.2 m.p.h. on the Rheims circuit, which broke the 114.86 m.p.h. put up during the 1939 race by Lang on the Mercedes-Benz, and came very near to the 117.5 m.p.h. put up by the same combination in practice. Despite the advantages of more recent design and substantially greater piston area the l½-litre two-stage Ferrari was quite unable to challenge the older Alfa Romeo models, although it should be recorded that right at the beginning of the season (in mid-April) it took second place in the San Remo Grand Prix and was faster than the Type 158 over a lap but at a speed of only 62.3 m.p.h. As this was also less than the 62.87 m.p.h. recorded by a Maserati in 1949, the figures have no significance. On the Spa, Monaco and Berne circuits, in the races run between May 21st and .June 18th, the blown Ferrari was obviously outclassed, the fact of the matter being that it was, if anything, slower than the Alfa Romeo in its 1948 form.

Only two of these cars appear to have been constructed and the main effort of the Ferrari factory in 1950 was a bold attempt to challenge the apparently invincible l½-litre supercharged type by a modern interpretation of the 4.5-litre unsuper-

charged alternative. As before stated, nothing in the previous history of Formula I racing lent any support to the notion that this was a hopeful proceeding, but there were, nevertheless, theoretical considerations which at least justified the attempt. These are dealt with on a later page, and it will suffice to say for the moment that there were also practical reasons for this line of attack.

The combination of 8,500 r.p.m. with 3,900 ft./min. piston speed and 360 lb./sq. in. b.m.e.p. limited the life between overhauls of an Alfa Romeo engine to one event only, and maintenance on this scale was prohibitively expensive to a company like Ferrari which relied solely upon starting and prize money to justify the economic aspect of Grand Prix racing. It was largely for this reason that Ferrari entrusted Aurelio Lampredi in September, 1949, (when the twin-camshaft, two-stage supercharged engine of Colombo was already completed) with the task of laying out an unsupercharged engine which could be installed in the same chassis. The first Lampredi version-a Vee twelve-cylinder having a swept volume of 3.3 litres-was put on the test-bed in March, 1950, and ran in the sports-car class of the Mille Miglia race on April 23rd. It made a first appearance in a racing car on June 18th at Spa, on which circuit it was 2 seconds slower than the two-stage supercharged model from the same factory. In its second appearance in the Grand Prix des Nations on July 30th at Geneva it proved in practice faster than all the Alfa Romeos with the exception of that driven by Fangio, but on this occasion the engine had been modified to increase the swept volume to 4.1 litres. In the race itself Ascari held second position for over half distance.

Development of the model was continued by further enlargement to 4½ litres for the Italian Grand Prix held on September 3rd and in practice for this event the car not only broke the existing lap record by a handsome margin (reaching 118.75 m.p.h.) but was only 0.2 seconds slower than the Alfa Romeo driven by Fangio, and 1.4 seconds faster than any other Alfa Romeo. In the last race of the season (Penya Rhin Grand Prix at Barcelona on October 29th) three of these unblown Ferraris (one of them with a 4.1-litre engine) had, in the absence of Alfa Romeo, no opposition owing to the comparatively poor showing of the B.R.M., of which so much had been expected.

The B.R.M. design may be considered the apotheosis of the 1½-litre supercharged type with a sixteen-cylinder engine designed to run at between 10,000 and 12,000 r.p.m. and to develop over 400 h.p. Built under the sponsorship of Raymond Mays and Peter Berthon, who had been responsible for the pre-war E.R.A. models, it represented the co-operative efforts of a large number of British component and automobile manufacturers and the first model was shown to a selected audience in December, 1949. During 1950 the car appeared on the starting line twice. On the first occasion it failed to leave it and at Barcelona one car failed after completing two laps only, whilst another ran for two-thirds of the full distance before retiring when in fourth place.

Of the remaining competitors in Formula I racing, the most prominent were Maserati and Talbot. The former won the Grand Prix of Czechoslovakia and the latter the Dutch Grand Prix, but whereas the Italian car, bereft of works support, showed on the year's results an actual recession in average-speed index, the Talbot showed a very useful advance on the previous year's form. As set out subsequently neither could approach the performances of the Alfa Romeo and Ferrari cars, and, as one might reasonably expect, the increasingly elderly E.R.A.s receded still further into the background.

Having shown by their performances in September and October of 1950 that a twelve-cylinder, unblown 4½-litre car with 93 sq. in. of piston area was very nearly a match for a two-stage supercharged model with eight-cylinders and 33 sq. in. of piston area, everyone anticipated an extremely keen struggle between these rival concepts as exemplified by Ferrari and Alfa Romeo during the 1951 season. These hopes were not disappointed. Both makes improved materially upon their speeds of the previous year and Alfa Romeo retained a very slight advantage in speed over Ferrari which enabled them to win the world's championship. But for the first time, and against all the indications of only two years previously, the unsupercharged cars scored three decisive victories on such widely differing courses as the Silverstone aerodrome perimeter, the Niirburg Ring and Monza.

The issue was joined first on May 27th on the Bremgarten circuit at Berne which was won in heavy rain by Alfa Romeo from Ferrari by a margin of under one minute, after the Alfa Romeo, in practice, had lapped at 104.46 m.p.h. as compared with the best Ferrari of 102.22 m.p.h. Both cars, it will be noticed, were much faster than the best speed of 1950, which was 100.47 m.p.h. by Alfa Romeo.

The same train of events ensued on June 17th in the Belgian Grand Prix at Spa. When the current revised circuit was first used for this event in 1950 the Alfa Romeo had put up 115.15 m.p.h. and the 3.3-litre Ferrari 108.9 m.p.h. In 1951 Fangio on the Alfa Romeo achieved 120.51 m.p.h. during the race itself. In practice the fastest Ferrari achieved 116.5 m.p.h. and the two cars entered took second and third positions after the fastest Alfa Romeo driven by Fangio had been delayed by a newly designed wheel failing to come off the splined hub.

These very big gains in speed so early in the season showed that the stories which had circulated during the spring of 1951 regarding the greatly increased power output of both cars were not amiss. An extension of the Ferrari output from around 330 h.p. at 6,500 r.p.m. to some 380 h.p. at 7,500 r.p.m. was a logical expectation for even at the higher rating both piston speed and b.m.e.p. were moderate. By contrast, the extraction of yet more power from the Alfa Romeo was a real feat of legerdemain and it was claimed that with even higher supercharge pressure from the two-stage Roots blower the engine output was over 400 b.h.p. at over 10,000 r.p.m. and more than 4,600 ft. min. piston speed. The very high resultant stresses, mechanical and thermal, could only be dealt with by running on very rich mixtures of alcohol fuel with exceedingly large valve overlap. This reduced the fuel consumption to below 1.5 m.p.g. and enforced the use of 65-gallon fuel tanks, as a consequence of which the fuel weight was over 5 cwt. and represented about 20 per cent of the total weight of the car. This upset the handling qualities and made it impossible to use full power until the tank had been partly emptied, thus imposing a restraint on the driver at least twice during the course of a race.

During the year, some of the Alfa Romeos appeared with simple de Dion type rear axles in place of the usual swing axle arrangements and all of them had wider and stiffer brake drums. There is no evidence that the change in axle construction had any decisive influence on lap speed, but as shown in the technical analysis which appears later the improved brakes, plus developments in the suspension system in the way of new shock absorbers, must have played quite a large part in the very large gain in speed witnessed during the year.

The extent of this gain was shown to the full on July lst, on the Rheims circuit, in the course of a dramatic struggle for the Grand Prix d'Europe. In practice for this event, which proved the first of three which had unique historic importance, both Ferrari and Alfa Romeo broke not only existing Formula I records but also the long-standing figures set up in 1939 by the 3-litre Mercedes-Benz. Fangio on the fastest Alfa Romeo put in a circuit at 119.99 m.p.h., and Ascari on the Ferrari reached 117.95 m.p.h. That this was not a flash in the pan is shown by the fact that, despite being forced to change cars during the race, Fangio secured a victory for Alfa Romeo at 110.97 m.p.h.-a really astonishing increment over the 104.83 m.p.h. set up over a shorter distance in 1950 and exceeding by a clear 5 m.p.h. the previous fastest speed for the race-distance set up by Muller on the 3-litre Auto Union, who averaged 105.25 m.p.h. in 1939. This was the first occasion a Formula I car had broken a speed record set up by a pre-war car, and it was but a fortnight later that another happening unique of its kind was witnessed. In the British Grand Prix held on the Silverstone circuit a car powered by an unsupercharged engine defeated the supercharged models, when Gonzales on the Ferrari showed himself the master of Fangio on the Alfa Romeo ; and although Farina on one of the latter made the fastest lap of the race he did not quite equal the speed put up by Fangio in practice. This was not the first occasion in which an unsupercharged engine had beaten a supercharged type under the Formula I regulations, for most of the Talbot wins had been at the expense of Maserati. It was, however, the first time since June, 1946 (St. Cloud), that the Type 158 Alfa Romeo had been defeated, thus ending an unbroken run of twenty-five successes in five-and-a-half years, which is the longest sequence of victories, whether measured by years or number, of any single make or type in the whole history of motor racing.

The Nürburg Ring, where the German Grand Prix was staged on July 29th was the setting for the third unique event in one month. This was a win for the unblown type of car at a record average speed for the entire race distance, Ascari's average on the Ferrari of 83.76 m.p.h. being appreciably faster than the previous record held by Caracciola who, in 1937, averaged 82.77 m.p.h. on the 5.6-litre Mercedes-Benz.

Fangio on the Alfa Romeo put up the fastest lap ever seen during a German Grand Prix but just failed to equal a lap put up in 1939 by Lang on the 3-litre Mercedes-Benz during his victorious drive in the Eifelrennen which was, however, run over ten laps as against the twenty laps which had to be covered in 1951.

Ferrari won the Italian Grand Prix, and their third Grande Epreuve in succession, at Monza. Alfa Romeo appeared with modified cars called the Type 159, all with de Dion rear suspension, extra fuel tanks, and air intake to the carburetters through the scuttle, and these models showed an astonishing speed in practice. They advanced their previous best of 120.97 m.p.h. (set up in 1950) to 124.53 m.p.h. which is the highest speed ever recorded on a European circuit. Ferrari also broke the previous record with a speed of 122.5 m.p.h. They had modified bodies, shorter scuttles and longer tails which embraced larger fuel tanks.

Only one event now remained in the 1951 World Championship. As Alfa Romeo had won the first three Grandes Epreuves and then Ferrari in turn had brought off a hat trick, the winner of the Spanish Grand Prix (which was also the Eleventh Penya Rhin) would, *ipso facto,* be the winner of the World Championship. Ferrari had the advantage of experience in 1950 whereas Alfa Romeo came fresh to the scene. It is

all the more surprising that it was the more experienced company which made the mistake in tactics which cost them dear. Ferrari decided to enlarge the tyre section and to use a 16-in. rim, whereas Alfa Romeo employed an 18-in. rear wheel with a smaller cover. Ferrari's experiment proved disastrous as the sustained speed possible on the straight, which is 1¾ miles long, resulted in the loss of tyre treads, and the loss of the race itself. Hence, although Ascari put in a practice lap on a Ferrari at 108.1 m.p.h., which compares with the 98.2 m.p.h. by the same model on the same course the previous year and with 106.9 m.p.h. by Alfa Romeo, the latter won the race and the World Championship, The overall speed of 98.76 m.p.h. for 275 miles compares with the Ferrari speed of 93.8 m.p.h. for 196 miles in the previous year.

In sum, the speed of both Alfa Romeo and Ferrari increased by nearly four per cent from one racing season to another and to all intents and purposes both were as fast as the 3-litre Mercedes-Benz and Auto Union cars which ran in 1939. Within five years, therefore, the historic process whereby the cars of a new Formula equal the speeds of the cars built under the preceding Formula had been re-enacted.

The differences in speed between Alfa Romeo and Ferrari during the whole year may perhaps best be realised by imagining that they had been asked to cover a single lap 43.1 miles long made up of the circuits at Berne, Spa, Rheims, Silverstone, Nürburg Ring, Monza and Barcelona, put, as it were, end to end. The fastest Alfa Romeo would have covered this lap (about equal in length to the Dieppe circuit of 1912) in 26 mins. 25.2 sets. at a speed of 97.8 m.p.h. and the fastest Ferrari would have come past 12.6 seconds later at an average speed of 97.1 m.p.h. The total eclipse of all rivals to these two Italian cars can perhaps best be appreciated by a safe estimate that none of them would have reached an average of even 90 m.p.h. on such a hypothetical circuit.

Dealing with the race record of " the field " in detail, the gallant, aged E.R.A.s virtually disappeared from the racing scene and with lack of works support for both Maserati and Talbot cars the speed reached by these models on a circuit was in many cases less than that reached in previous years. The Talbots, however, continued to pick up a number of places, whereas the decline of Maserati was almost absolute, as the sole " success " of the season was a third place at Pau.

Once again, the B.R.M., the only make that could in theory challenge the Italian models, failed to do so in practice. Two cars made a last-minute appearance on the starting-line in the British Grand Prix in mid-July and they ran without mechanical failure and finished in fifth and seventh positions. Following this, two cars were entered for the Italian Grand Prix but both gave trouble in practice and failed to start. After this, tests continued to be made on the Monza circuit and a lap speed of 120.5 m.p.h. was reached. We can thus say that the B.R.M. in 1951 was appreciably faster than the Alfa Romeo and Ferrari models of 1950, but substantially slower than the contemporary editions of these makes.

When Formula I was agreed at a meeting of the Federation Internationale de 1'Automobile on February 28th, 1946, it was intended that it should cover the years 1947, 1948, 1949, 1950 and 1951. In October, 1951, the F.I.A. decided to extend the life of Formula I up to the end of December, 1953, that is to say, by a further two years. It simultaneously announced that from January 1st, 1954 onward, the Grand Prix Formula would be based upon a capacity limit of 2½ litres for unsupercharged engines and 750 c.c. with supercharged engines.

Following this Alfa Romeo decided that their basically 1937 design of 1½-litre car could not usefully be run for two more seasons and Mercedes-Benz concluded that with only two more years of life for the Formula it would be impolitic to construct the 1½-litre supercharged cars which they had been completing on the drawing board. This left the 4½-litre Ferraris unchallenged, unless B.R.M. could prove that in the extended life of the Formula it was going to redeem the theoretical promises which had failed to materialise during the previous three years. If it did not then organising clubs, needing inter-make competition to attract the crowd, would have to run their races on the basis of Formula II, which limited unsupercharged cars to a swept volume of 2,000 c.c. and supercharged engines to 500 c.c.

It is possible that this broad question was decided on April 6th, 1952. During March the B.R.M. team had been carrying out extended tests at Monza and it was hoped that on this date they would show their ability to compete with the 4½-litre Ferraris on the St. Valentine circuit just outside Turin, where a race over 156 miles was held. The B.R.M. organisation decided, however, to bring the cars back to England from Monza for modifications, so the race itself was won without British opposition by Villoresi on a 4½-litre Ferrari with another Ferrari, handled by Farina, making fastest lap at 70.12 m.p.h. This sufficed to confirm general opinion that the B.R.M. was not yet ready to race, and that it would be necessary to base all the Grandes Epreuves on Formula II. In consequence, during the whole of 1952 and 1953, Formula I racing was degraded to minor events on the International Calendar, most of them run over short distances.

In 1952 Ferrari was unchallenged. The Turin race was followed by Albi, where two B.R.M.s started. One, driven by Fangio, made fastest lap at 114.58 m.p.h. in practice, Gonzalez made a record race lap at 106.97 m.p.h. and both cars led the field for the first five laps. But at this point Gonzalez retired with engine trouble, Fangio following with the same difficulty on the sixteenth lap, leaving Rosier to win on a 4½-litre Ferrari at 101.9 m.p.h. for 188 miles. In the following events of the season a 4½-litre Ferrari, modified by Mr. A. G. Vandervell, the bearing manufacturer, and called the " Thin-Wall Special " made fastest lap and won a 252-mile race in Northern Ireland on the Dundrod circuit, the car being driven by Taruffi. The same car and the same driver won a 100-mile *formule libre* race at Silverstone on July 19th, with a works Ferrari, driven by Villoresi in second place, and on August 4th this works model won a 200-mile race at Boreham, other Ferraris being second and fourth, with a 4½-litre Talbot third. The two B.R.M.s entered in all of these events retired with various mechanical troubles, or spun off the road but, at Silverstone, Gonzalez tied with Taruffi with a record lap at 96.67 m.p.h.

On August 23rd, at Turnberry, the B.R.M. secured a first win of the season (and the second of its career), gearbox trouble in the Thin-Wall Ferrari giving Parnell a 10-seconds lead over Gaze driving a pre-war 2.9-litre Maserati. On September 27th, at Goodwood, however, a full team of B.R.M.s was brought to the line for the first time to run over fifteen laps of a 2.4-mile circuit. Here the cars had a 1, 2, 3 finish, Gonzalez winning and Parnell breaking the course record at 90.38 m.p.h. This impressive performance was somewhat tarnished when a single car, entered for the last meeting of the season at Charterhall, was beaten by a 2-litre E.R.A. of 1937 construction.

But during 1952 the B.R.M. was at least becoming a reliable as well as a fast car, and during the winter of 1952-3 the assets of B.R.M. were taken over by Mr. A. G. B. Owen. For 1953 the cars were entered for all possible events under this new sponsorship but, with one exception, Ferrari wholly withdrew from the Formula I field, and indeed only one race under this rating was held outside the British Isles.

This was at Albi, on May 31st, in which three B.R.M.s, driven by Fangio, Gonzalez and Wharton, were opposed by Ascari on a works Ferrari, and Farina on the Thin-Wall Special, the latter now considerably modified from the original design.

The race was run in a 50-mile heat and a 100-mile final, and by the third lap of the heat the B.R.M.s were in the first three positions and the works Ferrari had retired with a broken gearbox. Farina's car also broke down before the finish. The final opened with the B.R.M.s demonstrating complete superiority of speed, but on the thirteenth lap Wharton had trouble which resulted in the car leaving the road and overturning, and the other members of the team were delayed by tyre failures. This led to the withdrawal of Fangio owing to a damaged hub and Gonzalez, although catching up, finished 30 seconds behind Rosier on a privately owned 4½-litre Ferrari. During the race Fangio lapped at 115.57 m.p.h. which broke all previous records.

Earlier in the year Wharton beat Taruffi on the Thin-Wall at Goodwood (March 6th) and later the same driver and car won at Charterhall (August 15th).

At last, and some five years after the design had left the drawing board, the B.R.M.s had established real mechanical reliability, although they still suffered from overweight and the characteristics of the centrifugal blower made them difficult to drive, especially if wheelspin was allowed to develop. Mainly for these reasons the full team of B.R.M.s was twice beaten by the lighter, if less powerful, Thin-Wall Special. At Silverstone in a 50-mile race the Thin-Wall was the only car to achieve a 100 m.p.h. lap which it did during the race itself. Although not quite equalling the speed of the works 4½-litre Ferrari on the same circuit in 1951 there had been small changes in the intervening two years which had made the course appreciably slower so that the 100.16 of Farina in 1953 probably equalled about 103 m.p.h. in 1951. The highest speed of the B.R.M. was 99.41 m.p.h. or the equal of about 102 m.p.h. in 1951. Over the 50 miles the Ferrari had a margin of 11 seconds, but this does not take account of the fact that for the last 15 miles it was deliberately being driven slower than the B.R.M. in view of the considerable lead it had built up.

The Thin-Wall confirmed its superiority at Goodwood on September 26th, when Hawthorn raised the lap record to 94.53 m.p.h. and beat a B.R.M. by 23 seconds in 36 miles.

This was the last contest between the supercharged l½-litre type of car and the unblown 4½-litre within the legal limit of Formula I. It is unfortunate that during the last two years of the Formula the cars did not appear on any of the classic courses, and it may well be thought that racing under this rating rule ended " not with a bang but with a whimper " A more correct perspective will be gained by agreeing that Formula I ended, in fact, on the date at which it was originally intended to expire - that is to say, December 31st, 1951. We shall then see that it served its purpose admirably by bringing together in the immediate post-war period of 1947-8 a miscellaneous collection of racing cars of basically pre-war design, amongst which the Type 158 Alfa Romeo predominated, with intervention from Maserati and the unsupercharged Talbot.

During 1949, in the absence of Alfa Romeo, Maserati and Talbot competed on very level terms, but after a year of absence from racing, and of intensive development, the works Alfa Romeos carried all before them in 1950. At the end of 1950 they were, however, successfully challenged by the twelve-cylinder, unsupercharged 4½-litre Ferrari, and although in 1951 the supercharged cars retained the world's championship title which they had gained previously in 1947, 1948 and 1950 they did so by the perilously small margin of four wins compared to Ferrari's three. The competition between these two makes in 1950 and 1951 brought lap and race speeds up to a level comparable with those achieved by the 500 and 600 h.p. cars of the immediate pre-war period. There was, therefore, a general feeling that the adoption of Formula II as the basic Grand Prix rating for 1951 and 1952 would lead to a very obvious reduction in speeds and a corresponding loss of spectator appeal. The events run under this Formula will be considered in the next chapter, but it is only fitting to end this review of Formula I with a summary of the astonishing racing record of the Type 158 and 159 Alfa Romeo cars in the four seasons in which they competed. In this period the company made ninety-nine separate entries in thirty-five races. Of these they won all but four, so that they had thirty-one victories together with nineteen second places and fifteen thirds. They made fastest lap in twenty-three of the races and suffered only twenty-eight retirements. The highest standard of reliability was reached in 1947 with no retirements from an entry of eighteen cars which covered in all 3,093 racing miles. The worst, as one might expect, was eight retirements out of thirty-four cars run over 5,478 miles in 1951. Taking into account retirements, the cars raced a total of 18,153 miles under Formula I (plus 854 miles in 1946)-an average of 6,800 racing miles per car for an overall reliability factor of 81 per cent. This is a record of reliability and success without parallel in motor-racing history.

CHAPTER TWO

The Mastery of Modena

RACING STATISTICS 1952-3

Date	*Event*	*Circuit*	*Driver*	*Car*	*Winning average Speed*	*Lap Speed m.p.h.*
12/4/52	Pau G.P.	Pau	A. Ascari	Ferrari	56.48	—
10/5/52	B.RD.C.	Silverstone	L. Macklin R. Fischer	H.W.M. Ferrari	85.41 —	89.29
18/5/52	Swiss G.P.	Berne	P. Taruffi G. Farina	Ferrari Ferrari	92.78 —	97.19 (P)
25/5/52	Eifelrennen	Nürburg Ring	R. Fischer	Ferrari	77.25	—
22/6/52	European G.P.	Spa	A. Ascari	Ferrari	103.13	114.03(P)
29/6/52	Rheims G.P.	Modified Rheims	J. Behra A. Ascari	Gordini Ferrari	105.33 —	110.04(P)
6/7/52	A.C.F. G.P.	Rouen	A. Ascari	Ferrari	80.14	84.63 (P)
19/7/52	British G.P.	Silverstone	A. Ascari	Ferrari	90.92	95.79 (P)
3/8/52	German G.P.	Nürburg Ring	A. Ascari	Ferrari	82.21	84.4
17/8/52	Dutch G.P.	Zandvoort	A. Ascari	Ferrari	81.15	92.4 (P)
7/9/52	Italian G.P.	Monza	A. Ascari	Ferrari	109.8	112.04 (P)
6/4/53	Pau G.P.	Pau	A. Ascari	Ferrari	60.5	62.5*
9/5/53	B.R.D.C.	Silverstone	M. Hawthorn	Ferrari	92.29	94.93
31/5/53	Eifelrennen	Nürburg Ring	E. de Graffenried	Maserati	70.24	—
7/6/53	Dutch G.P.	Zandvoort	A. Ascari	Ferrari	81.04	84.42 (P)
21/6/53	Belgian G.P.	Spa	A. Ascari J. M. Fangio	Ferrari Maserati	112.47 —	117.3 (P)
5/7/53	A.C.F. G.P.	New Rheims	M. Hawthorn J. M. Fangio	Ferrari Maserati	113.65 —	15.91
18/7/53	British G.P.	Silverstone	A. Ascari	Ferrari	92.97	97.57 (P)
2/8/53	German G.P.	Nürburg Ring	G. Farina A. Ascari	Ferrari Ferrari	83.89 —	— 85.62
23/8/53	Swiss G.P.	Berne	A. Ascari J.M. Fangio	Ferrari Maserati	97.17 —	101,72 (P)
13/9/53	Italian G.P.	Monza	J.M. Fangio A. Ascari	Maserati Ferrari	110.69 —	— 114.86 (P)

THE agreement to use Formula II in the Grand Prix racing of 1952-3 followed decisions taken by the F.I.A. five years previously. From the earliest days of International motor racing comparatively few works-supported events run under the Grand Prix regulations have been supplemented by a large number of minor events attracting skilled amateurs, and the less skilled professionals, driving cars of comparatively low engine output. Thus in 1910-3 there were races for 3-litre cars developing about 90 h.p. and from 1921 until 1938 a large number of races were held for cars of 1½-litre capacity, giving at first about 55 b.h.p. unsupercharged and just before World War II approximately 200 b.h.p. in supercharged form.

The International Racing regulations which made supercharged 1½-litre cars the full Grand Prix type produced, therefore, the historical necessity for a supplementary rating governing cars of lesser power and speed. It was agreed that from 1948 onwards there should be a Formula II for cars having engines of not more than 500 c.c. if fitted with superchargers, or 2 litres if unsupercharged, the expectation being that this would limit power to 100 and 125 b.h.p. A number of new designs were introduced to run under this rating.

Gordini, working in conjunction with Simca in France, built some very small and light cars using basically an 1,100 c.c. Fiat engine which was, however, enlarged to 1,490 c.c. A similar type of engine was used by Dusio in the Turin-constructed Cisitalia, which was the first post-war car to use a space-type frame made up of a large number of small diameter steel tubes. On these cars the engines were enlarged to 1.3 litres. In England the H.W.M. appeared with a four-cylinder, 2-litre Alta engine built into a chassis which was based on production car parts, including Standard suspension units, Citroen steering gear and a pre-selector epicyclic gearbox. Constructed in the first year as two-seaters, the cars were in 1949 changed to single seaters and in due course ran with normal gearboxes, a de Dion axle with inboard brakes and a space-type frame. Connaught also used a four-cylinder engine based on a production-type Lea Francis with inclined overhead valves operated by push-rods.

All these cars, which used modified production-type components, had to compete against a specialised design sponsored by Enzo Ferrari, which had a 2-litre, twelve-cylinder power unit which could be run at about 7,500 r.p.m. or about 2,000 r.p.m. more than the four-cylinder engines which opposed it. With over 150 b.h.p. transmitted through a five-speed gearbox it is surprising Ferrari were ever challenged for first place, but, in fact, during the first season of racing in 1948 they were beaten by a Simca at Perpignan, by a Cisitalia at Mantua, and by an 1,100 c.c. OSCA at Naples. In 1949 the Ferrari appeared in a new short chassis with independent rear suspension and during this year a works-entered Ferrari was beaten but once (by a Simca at Lausanne) and won six events, in each of which it made also the fastest lap. In 1950 the cars were revised again, using a longer wheelbase chassis and a de Dion type rear axle with engine output raised to about 170 b.h.p. In this season again they were beaten but once (again by a Simca, now at Geneva) and once failed to make the fastest lap, when this was put up by an H.W.M. driven by Moss on the Caracalla circuit at Rome.

Some idea of the speed of the cars at this time can be had from a lap at 101.41 on the Rheims circuit, which compares with the 99.5 m.p.h. put up by the 2.65-litre supercharged Alfa Romeo in 1932.

In 1951 Ferrari again won all the important Formula II races, but Simca took first place in four minor events and H.W.M. also were placed in some of the Continental races. It was late in this year that Lampredi, who had succeeded Colombo as Chief Engineer of Ferrari, designed and built within 100 days the four-cylinder " over-square " Ferrari engine which dominated Grand Prix racing in the two succeeding years, as will now be described in some greater detail.

When first put on the test-bed this engine gave about 160 b.h.p. and by the end of 1952 this had been brought up to between 180 and 190 b.h.p. Considerably lighter than the twelve-cylinder power unit and with better torque in the low-speed range this big-bore four was challenged by a number of new cars seeking honours in the interregnum before the new Grand Prix Formula of 2½ litres determined for 1954 and onwards came into being.

The fastest and most powerful of these rivals was a six-cylinder, two overhead camshaft Maserati ; the lightest, and most immediately competitive, a six-cylinder Gordini. The fastest British car was the established Connaught, but new designs came from Cooper and E.R.A., both of whom used the six-cylinder, long-stroke Bristol engine which had been developed from the pre-war 328 B.M.W.

The technical details and comparative speeds of these vehicles are set out in another chapter. The race results of the years 1952 and 1953 are an almost monotonous catalogue of first place for Ferrari, with Ascari at the wheel and he was world champion in both years. Alberto Ascari is the son of the 1925 world champion, and he commenced his 1952 successes early in the year with a win in Syracuse on March 16th. On April 14th the Bristol-engined Cooper made a sensational first appearance on the Goodwood circuit, putting in a lap at 87.28 m.p.h. in the hands of an almost unknown driver, Mike Hawthorn, who was to achieve world fame within a year of his first appearance in a modern car. During the same week-end Ascari won at Pau and a fortnight afterwards he won again at Marseilles, with the new six-cylinder Gordini, driven by Manzon, in second place.

The B.R.D.C. Silverstone meeting at the beginning of May attracted two privately owned Ferraris and two works Gordinis, all of which were beaten by Macklin in the H.W.M., and in the Swiss Grand Prix in the same month Ferraris were first and second, with the Gordini third. In the European Grand Prix, held in the rain, Ascari again won with Farina's Ferrari second, a Gordini third and Hawthorn, on the Cooper, in fourth place.

A week later Ferrari suffered their one defeat of the year on the very fast Rheims circuit, being beaten by a Gordini after both Ascari and Villoresi had retired with mechanical trouble. In practice Ascari had lapped at 110.04 m.p.h. and the Gordini at 109.6 m.p.h., but these speeds cannot be compared with any previous lap times as the course was modified for 1952 by eliminating one of the slowest corners.

During July the Ferrari team took the first three places in the A.C.F. Grand Prix run on a new circuit at Rouen, and were first and second in the British Grand Prix with Hawthorn third, a long way behind, on his Cooper. In this race Poore might well have taken third place (which he held for a long period) if alcohol fumes had not rendered him semi-conscious for the last few laps of the race. In August Ferrari took command of the German Grand Prix with the first four places, followed by the first three in the Dutch Grand Prix with Hawthorn, on the Cooper, again the most successful

of the rival makes. Finally, in September, came the first hint of a serious challenge in the form of developed Maseratis which had higher power output than the Ferraris, giving them better acceleration and greater maximum speed. But with comparatively inadequate brakes and the retention of a rigid rear axle they were not able to break the Ferrari sequence of victories, although Gonzalez led until he stopped for fuel; the Ferraris with larger tanks and a better consumption were able to run through non-stop. At a minor meeting at Modena, held a week later, Gonzalez chased Villoresi home at a distance of a car's length and put in the fastest lap.

It had been generally feared that the lower power of the Formula II cars would reduce certain speeds to such an extent that Formula II racing would appear but a pale shadow of the dramatic struggles which had been witnessed in the past two years under Formula I. A study of the lap speeds put up during the year show that on the faster circuits there was indeed a very material reduction, the loss at Monza, for example, being over ten miles an hour. But on the slower circuits there was little significant change and, on average, the cars had to be driven for over 50 miles before they lost a minute compared with their twice as powerful predecessors.

The 1953 season began with yet another Ferrari-cum-Ascari victory, this time in the minor event at Pau, followed a month later by a win for his new team-mate Hawthorn in the Silverstone race organised by the B.R.D.C. The Dutch Grand Prix was the first of the Grandes Epreuves on the calendar and the drivers were seriously distressed by a remade road which left a very slippery surface which only Villoresi could disregard. In practice, Fangio on a Maserati was little slower than Ascari, but he had mechanical trouble in the race and the Ferraris finished first and second with a Maserati one lap behind. In the Belgian Grand Prix Fangio put up the fastest lap in practice, beating Ascari by two seconds, Farina by four seconds and Villoresi by seven seconds. Moreover, in the race itself, Ascari was forty-nine seconds behind the Maserati on the ninth lap which seemed to show that as a design the Ferrari had at least met its match. However, Gonzalez' car, running second, broke down on the eleventh lap and Fangio's car disintegrated two laps later.

The inter-Italian battle was renewed with even greater intensity and over the full race distance, in the A.C.F. Grand Prix, now returned to the traditional Rheims circuit.

Once more the course had been modified to make it faster so that no useful comparisons can be made with previous years. Practice showed that the Ferrari and the Maserati were matched within 0.3 of a second and in the stress of the race Fangio actually put up a higher speed in the race than anything achieved in practice. The Maserati team played a cunning tactical game by sending off Gonzalez with his fuel tanks half full in order to lead from the start, which he succeeded in doing from the first to the twenty-ninth lap. From that point onwards Fangio took the lead challenged only, and surprisingly, by Hawthorn's Ferrari, who came up to a neck and neck struggle almost unique in the annals of motor-racing history. For example, on laps 32, 33 and 34 Hawthorn led by half a car's length, only to be passed by the same margin by Fangio on laps 35 and 36. Finally, however, Fangio, with weakening brakes and a loss of his second speed, had to concede victory by a mere second after a titanic struggle which had lasted for 22 hours. The average speeds for the race were : Hawthorn on the Ferrari, 113.65 ; Fangio on the Maserati, 113.64 m.p.h.

Interestingly enough, the season ended with a re-enactment of this struggle but with different drivers and a different ending. In the Italian Grand Prix at Monza, Ascari and Farina on Ferraris ran wheel to wheel with Fangio and Marimon on Maseratis after practice had shown the two cars were of equal speed within ½ second per lap. During this race the lead changed twenty-two times and throughout the whole 312 miles there was never as much as 2 seconds between the first and second cars. At half distance Ascari’s Ferrari led Fangio’s Maserati by 0.3 seconds, which was increased to 1 second with only five laps to go. Then on the last corner of the last lap Ascari got out of control when overtaking a slower car and Fangio got by to beat Farina’s Ferrari by 1.4 seconds. On this occasion the relative average speeds were : Maserati 110.69, Ferrari 110.67 m.p.h.

Between these two epic events Ascari won the British Grand Prix with two of his team second and third after Gonzalez, who had been running second with the Maserati, had been called in to the pits to investigate a leaking oil tank. In the German Grand Prix Ascari lost a wheel, and although he motored to the pits on a front brake drum and later changed cars with Villoresi, it was Farina who won the event. In the Swiss Grand Prix, however, Ascari became 1953 world champion and was never seriously pressed by the Maserati, although Fangio had made a slightly better time in practice. But, as in Germany, Ascari had trouble during the run, as he had to call at the pits to adjust a magneto which had moved to the full retard position. When this had been attended to he was in fourth place with only fifteen laps to go, but driving with true mastery, he passed successively Hawthorn, Marimon and Farina to win by 73 seconds.

As one might imagine, the 1953 cars were sensibly faster than the 1952 models and the year was indeed notable for the fact that, aided by non-stop runs, finishing speeds over the full distance were higher than the records established by the 600 b.h.p. 1937 Grand Prix cars on the circuits of the Nürburg Ring and Pau and superior to the 485 b.h.p. 1939 cars on these two courses and at Berne.

CHAPTER THREE

Carried Forward

IN the four seasons of motor racing which ended in 1939 only four makes of car were entered for Grand Prix racing, and of these only two makes succeeded in gaining a place in a race of major importance.

This makes a strong contrast with the post-war period in which eight makes were entered, of which five, representing nine types of car, finished in one of the first three places of a Grande Epreuve under Formula I, with eight makes also in the Formula II racing of 1952 and 1953. For this reason it is difficult to pick a single example of a Formula I (and equally of a Formula II) car as a representative of the technique involved under these respective regulations ; indeed, to do so could be misleading to the reader. The next three chapters of this volume will, therefore, contain brief descriptions of the leading makes and types of car involved in post-war Grand Prix racing, and they will be followed by detailed descriptions of the 1½-litre, sixteen-cylinder B.R.M. and the 4½-litre, twelve-cylinder Ferrari as being outstanding examples of engineering development in the alternative types possible in Formula I.

It is proposed to subdivide the Formula I cars into pre-war designs ; cars of new design, and to follow these with a chapter on Formula II cars. This first chapter will be restricted, therefore, to cars of less than 1½ litres capacity supercharged, or under 4½ litres unsupercharged, of which the prototypes were in being before 1939.

ALFA ROMEO TYPE 158/159

INTRODUCTION

This model was designed in 1937 at the request of Enzo Ferrari, who wished to have a l½-litre model available with which the Scuderia Ferrari could compete in the l½-litre races of 1938 and subsequently. The engine had the same bore and stroke as the 3-litre V.16 car which was being prepared for the Grand Prix Formula ruling at that time (3 litres supercharged and 4½ litres unsupercharged), and in many details, such as the cylinder-head layout, there was a close resemblance between the two models.

An initial batch of four 1.5-litre cars, which became known as the " Alfettas ", was put through. These were partly assembled by Ferrari at Modena and the engine was given its initial bench testing there, developing in the first instance 190 b.h.p. at 6,500 r.p.m.-the equal of 254 lb./sq. in. b.m.e.p. at 3,000 ft./min. The model made its first appearance on the Leghorn circuit when it won its class in the Coppa Ciano on 31st July and the best lap speed on this occasion was 85.64 m.p.h.

A fortnight later, when running on the Pescara circuit in the Coppa Acerbo, Severi was timed at 139.53 m.p.h., but the staying power of the car was not yet commensurate with its performance, and the whole team was forced to retire not only in this event, but also when running on the Modena circuit on 18th September.

For 1939, extensive modifications, more particularly a change over to a roller bearing crankshaft, were made. As reconstructed, the engine output was raised to 225 b.h.p. at 7,500 r.p.m. (or 260 lb./sq. in. at 3,450 ft./min.) and although beaten by

Mercedes-Benz at Tripoli, the cars had no difficulty in winning the three other events in which they were entered, viz. the Coppa Ciano, Coppa Acerbo, and the 1½-litre class of the Swiss Grand Prix. The best lap speeds of 90.8 m.p.h., 86.5 m.p.h., and 98.39 m.p.h. for the circuits in question. Considerable progress in the development of the car may be seen by comparing its performances on the Tripoli circuit in 1939 when it was defeated, and in 1940 when it won in the absence of Mercedes-Benz due to Germany being at war, Italy at that time remaining neutral. In 1939 the car driven by E. Villoresi into third place averaged 115.3 m.p.h., and the winning Mercedes-Benz averaged 122.9 m.p.h. A year later Farina averaged 126 m.p.h., and the best Alfa Romeo lap was 134 m.p.h., which compares with the best Mercedes-Benz figure of the previous year of 133.5 m.p.h. The post-war performance of the model has been set out in a preceding chapter.

CONSTRUCTION

The following constructional features of the Type 158 Alfa Romeo relate in the first instance to the design in its earliest appearance in Formula I, notes on development up to the end of 1951 being dealt with later.

Engine

The straight-eight engine comprises a light alloy crankcase split on the centre line of the crankshaft with dry sump lubrication. Oil is fed through an external gallery pipe to the seven main bearings and to an eighth outrigger bearing immediately adjacent to the flywheel. The scavenge pump draws oil from the rear end of the crankcase, the base of which is deeply finned, and surplus oil from the blower gears is also drained directly into the back of the sump. The cylinders are bolted on to the top face of the crankcase and consist of two light alloy castings bolted together, each containing four bores into which dry liners are inserted. A train of gears drives accessories and two overhead camshafts from the nose of the engine, also a Roots-type supercharger placed initially in the centre of the engine on the left side of the crankcase and inspiring through an updraught carburetter which feeds mixture directly to a manifold placed directly above it. Two valves per cylinder are used (with a 90-degree included angle), with central position for sparking plugs, and the water offtake is by four risers mounted on top of the cylinder head and placed on the centre line thereof.

The fuel pump is driven from the back end of the inlet camshaft, the oil and water pumps being driven from the front train of gears, as was a single magneto, held down by a strap on to the exhaust side of the camshaft. The water intake pipe is also bolted to the cylinder blocks directly beneath the exhaust ports.

Gearbox

The four-speed gearbox is mounted at the back of the car and is built up into one unit with the final drive which is fixed to the rear cross-member of the frame. Final drive ratios varying between 4 : 1 and 6 : 1 are available, the road speed on the higher ratio being approximately 22.5 m.p.h. per 1,000 r.p.m. Gears are selected by a gate mounted on the left-hand side of the cockpit, the oil tank being placed on the right-hand side thereof.

Rear Axle

Independent suspension on the swing axle system is employed, the wheels being located by a single triangulated arm joined to an inclined pivot so that wheel rise is accompanied by toe-in.

Rear Suspension

A single transverse spring passes below the main axle housing and is connected by pivot links to the rear hub. Hydraulic dampers of the direct-acting telescopic type and friction dampers have been used.

Front Suspension

At the front of the car, also, a low-mounted transverse leaf spring is connected to the wheel hubs which are located by two trailing arms. These terminate in pin joints so as to provide the required vertical and angular motion on the wheels.

Steering Gear

A worm and wheel gear is mounted directly above the clutch housing, a push-pull rod extending forwards beneath the exhaust system to a bell crank mounted on the front cross-member. The track-rods are split into two of equal length and are inclined slightly backwards.

Frame

The frame consists of two parallel rectangular section tubes mounted about 18 inches apart and joined by four cross-members.

Brakes

Hydraulic brakes are used.

Body and General Features

The fuel tank is contained in the somewhat long tail, the driver being centrally seated above the propeller shaft. The low-mounted radiator is enclosed by a cowl with an opening having the general proportions of a three-leaf clover, the air intake being covered by detachable plates to meet varying climatic conditions.

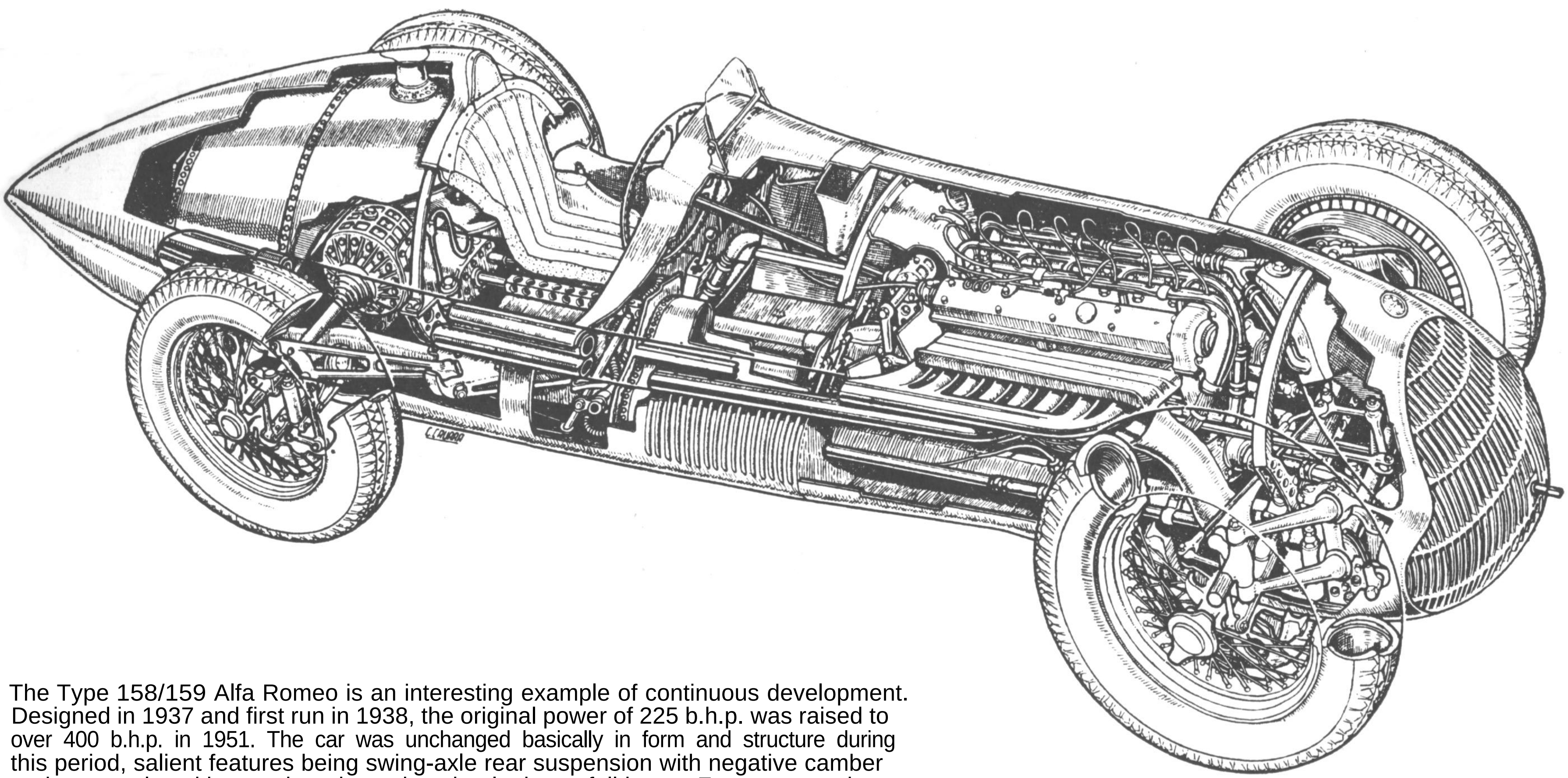
The obligatory driving mirrors are placed on the instrument panel within the body contour, and there have been alterations in the exhaust system between one single pipe and two pipes each fed from four cylinders. In each case the exhaust piping beneath the bonnet has been isolated by light alloy shields above and below it so as to protect the magneto from excessive heat and to maintain reasonable under-bonnet temperatures.

Dimensions

Wheelbase, 8 ft. 2½ in. ; Front and Rear track, 4 ft. 2 in.

DEVELOPMENT

Although the Type 158 was not dimensionally changed between 1947 and 1951, the engine output was very greatly enlarged (mainly as a consequence of a substantial rise in manifold pressure), and there have also been considerable changes in the chassis units. The engine output when the cars appeared in the immediate post-war racing of 1946 was 254 b.h.p. at 7,500 r.p.m., this representing a b.m.e.p. of 294 lb./sq. in. at 3,450 ft./min. However, as early as July, 1946, a car made its appearance with two-stage supercharging. This was contrived by placing an enlarged first-stage blower behind the original central blower, the first-stage component drawing mixture from a triple-choke downdraught Weber carburetter and feeding, through an inter-connecting pipe, into an updraught inlet port on the second stage. During 1947 the Type 158/47 was developed but not raced, but this model, having a larger primary blower and an output of 310 b.h.p. at 7,500 r.p.m. (358 lb./sq. in. b.m.e.p.), was used in practice for the Grand Prix de 1’A.C.F. in July, 1948, and in 1948 events.



The Type 158/159 Alfa Romeo is an interesting example of continuous development. Designed in 1937 and first run in 1938, the original power of 225 b.h.p. was raised to over 400 b.h.p. in 1951. The car was unchanged basically in form and structure during this period, salient features being swing-axle rear suspension with negative camber and a neutral position, and toe-in as the wheels rise to full bump. Front suspension is by trailing arms, transverse leaf springs being used fore and aft. As shown in this drawing the exhaust manifold of the eight-cylinder engine was isolated and fed with cold air ; on the intake side three down-draught carburetters feed two roots blowers giving two stages of compression. In 1951 the air to these blowers was drawn from the scuttle intake. In this year also supplementary fuel tanks were placed within the cockpit, the road consumption having degenerated to approximately 1½ m.p.g. owing to the necessity for using fuel as an internal coolant.

Air was ducted to the downdraught carburetters by a forward-facing trunk, this at first extending to about mid-point of the engine and on later models being carried forward to just behind the front spring. The exhaust system at first had a single discharge pipe but on later models the centre four cylinders and the two end pairs discharged into separate pipes.

After lying idle in 1949, detail changes in 1950 raised the output to 350 b.h.p. at 8,500 r.p.m. and even further development work was carried out during the winter of 1950-l.

In April, 1951, it was made known that an engine with even higher boost had been run upon the test-bed at 10,500 r.p.m. (4,750 ft./min.) developing 404 b.h.p. (345 lb./sq. in. b.m.e.p.) and 385 b.h.p. had been obtained at 9,500 r.p.m., viz. 352 lb./sq. in. b.m.e.p. at 4,300 ft./min. In view of this major increase, and in conjunction with certain chassis changes which are mentioned separately, this model was given the Type number 159.

Despite the shielding previously provided between the exhaust pipe and the magneto the latter was redisposed in a cooler place and driven from the front end of the inlet camshaft, whilst an interesting and significant revision of the water circulation was effected in 1947. The four offtake pipes, placed on the centre line of the head and between numbers 1 and 2 ; 3 and 4 ; 5 and 6 ; and 7 and 8 cylinder bores, were supplemented by four down pipes feeding high velocity cold water into the head immediately above the exhaust ports of cylinders numbers 2, 4, 6 and 8.

Reliance was placed increasingly upon internal cooling provided by the use of very rich mixtures of alcohol fuel having good values for latent heat, and of very large angles of valve overlap, to a point where this phase of the engine's operation was referred to in the Milan Design Department as a cooling " fifth stroke " As a direct consequence, fuel consumption fell to less than 1.5 m.p.g.

Turning now to chassis development, the rate of the front and rear springs was lowered with the introduction of the Type 158/47 and the fully developed Type 159 embodied a de Dion axle at the rear, this being adapted to the existing hubs, double-jointed half-shafts being provided on each side of the final drive.

Before this the spring links were arranged to place the half-shafts at a marked dihedral angle, the rear wheels thereby being given a marked inward inclination from bottom to top. For reasons which will be considered in a later chapter this arrangement improved considerably the stability of the cars when cornering.

Owing to the extremely high fuel consumption of the Type 159 a number of cars were built with side fuel tanks ; all the 1951 cars had additional fuel tanks built into the cockpit. The maximum tank capacity on this model was 65 gallons and on its last two appearances in 1951 (Monza and Barcelona) the forward-facing air intake was discarded in favour of a conduit drawing air from an orifice cut in the top of the scuttle, the Type No. 159 A being given to this final variation.

To match the very considerable gains in output, reflected in far higher acceleration and substantially greater maximum speed, the brakes were steadily modified through the years, and an illustration shows the very large diameter and wide brake drums used during the 1951 season.

E.R.A.

E.R.A. racing cars had their genesis in a supercharged, six-cylinder Riley two-seater which was built for the private use of Raymond Mays in hill climbs and short distance events, with the advice of Peter Berthon and T. Murray-Jamieson. The success of this car in 1933 led to a proposal by Humphrey Cook that he would finance a team of single-seater cars which could represent Great Britain in 1½-litre Formula racing. On this basis English Racing Automobiles, Ltd., was founded in 1934 and the vehicles about to be described succeeded in winning five major races in 1935 and 1936, eleven in 1937, six in 1938 and two in 1939, in which year a new but unsuccessful E type was produced to counter the arrival of the Alfa Romeo Type 158 and Maserati 4 CL models. The works produced a total of thirteen cars of A and B Type, characterised by single Roots blower mounted vertically at the front of the engine, semi-elliptic springs, and three C Type models with modified frames, superchargers, and front suspension systems. In the Formula I period only the 1939 model, or E Type, has received works backing, and owing to a large number of detail defects this model was withdrawn from racing in 1949. A number of private owners have, however, continued to race with the earlier A, B and C models which are about to be described.

CONSTRUCTION

The general layout and chassis design of the E.R.A. is highly reminiscent of the 1932-3 single-seater, 3-litre, Italian Grand Prix cars, and this is to some extent explained by the fact that Reid Railton, who was consulting engineer to Whitney Straight's team of Maserati cars in 1932-3, was retained as an advisor on the chassis design of the E.R.A.

Engine

The Riley-derived cylinder block is an iron casting in one with the crankcase and extends considerably below the centre line of the crankshaft. Unusual rigidity is provided by the high modulus of the cast iron itself and also by the box section of the crankcase into which the three-bearing crankshaft is inserted endwise, a Hyatt semi-flexible-type roller being used for the centre bearing. The main structure is also unusual, so far as racing cars are concerned, in using two camshafts, one on each side of the cylinder bores, each driven by a half-time wheel engaging with a gear on the nose of the crankshaft. The crank itself is heavily counter-weighted and nitrided and the rather long parallel section connecting rods have lead-bronze big ends with graphited-bronze main bearings.

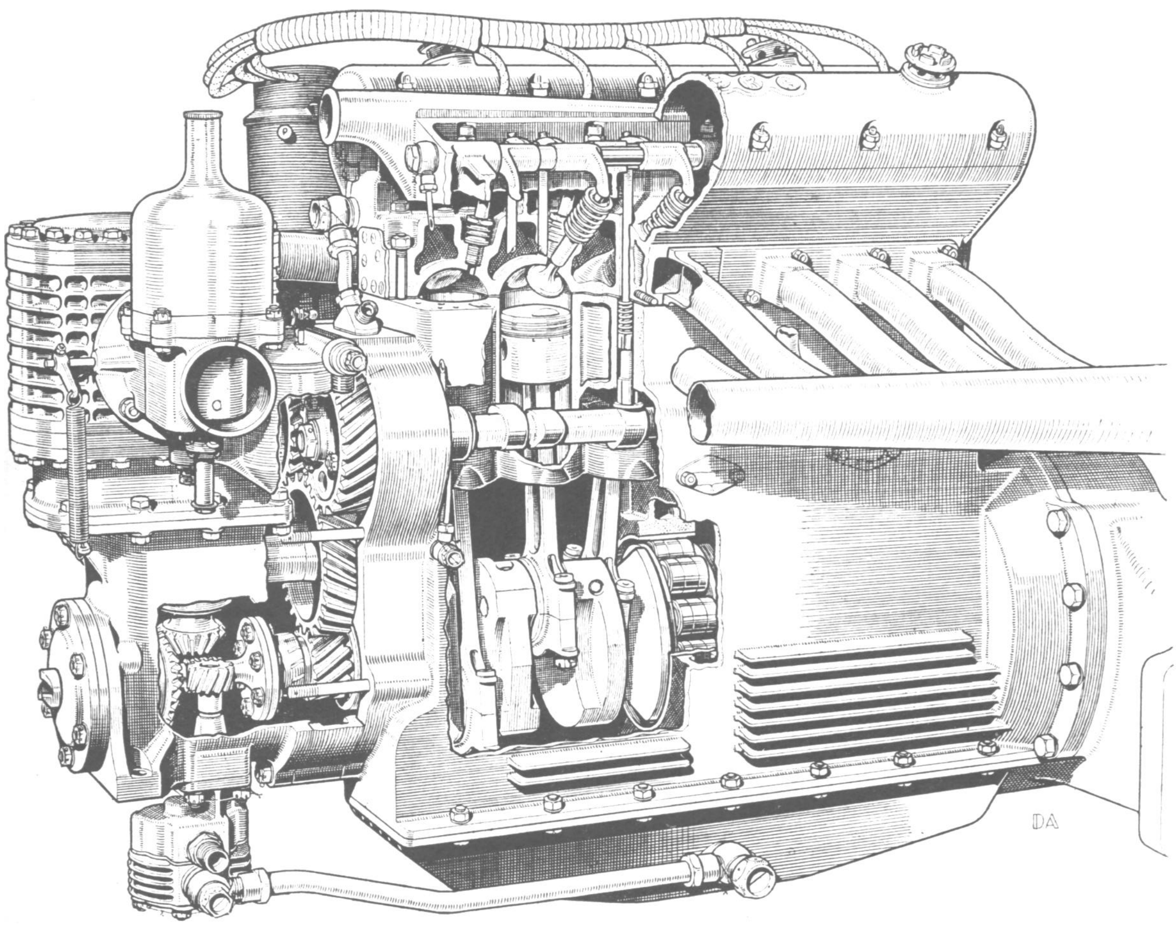
In order to keep the engine as compact as possible (the main engine casting is only 18 in. long) the cylinders do not have water spaces between them except above the centre main bearing, and the water jackets are also relatively short, the lower half of the bore projecting into the crankcase and being cooled solely by oil splash. A light alloy casting bolted to the nose of the engine encloses skew and bevel gears driving, respectively, oil pressure and oil scavenge pumps and a vertical two-lobe Roots-type blower of Murray-Jamieson design, drawing air from a single S.U. carburetter.

Mixture is fed through a pipe to individual inlet ports on the right-hand side of the light alloy cylinder head, each combustion space being of the hemispherical type with two inclined valves at 90 degrees. These are operated by the crankcase-mounted camshafts through short push-rods and rockers and the exhaust ports are of square

section in order to give the maximum area. The 18 mm. sparking plugs are slightly offset from the centre of the head and masked, and the stiffness of the head as a beam is considerably enhanced by the water riser which is formed at the inlet side as an integral portion of the casting.

A skew gear on the nose of the inlet camshaft drives a vertical magneto and despite the large stroke : bore ratio and the mass of the push-rod valve gear the engine has shown consistent reliability at crankshaft speeds of up to 7,500 r.p.m., the two weak spots being failure of the scavenge pump and breakage of the pistons and/or gudgeon pins.

The general arrangement described was also followed on the C type cars which secured most of the 1937 victories. A major change, however, was the fitting of a horizontal magneto on the platform previously occupied by the Roots blower and the mounting of a Zoller vane type compressor driven by gears from the back of the crankshaft and mounted above the gearbox. As a result of the internal compression and higher efficiency of this component the supercharge pressure was raised from 15 lb. (2 ata.) to 25 lb. (2.7 ata.) with a corresponding increase in engine power to 225 h.p. without increase in r.p.m. or piston speed. These compressors required more careful fitting and assembly than could readily be provided by private owners and for this reason the successful C type models used in Formula I racing have, almost without exception, reverted to the B type layout.



Although dominating the 1½-litre racing of 1935-7 and again prominent between 1947-9 the Roots supercharged E.R.A. engine was a very simple power unit with push-rod operated overhead valves, detachable cylinder head, cast-iron block and crankcase combined, and a three-bearing crankshaft. All of these features are shown in this drawing.

Gearbox

The drive is taken direct, i.e. without the intervention of a normal clutch, to a Wilson type epicyclic gearbox mounted in unit with the engine. The Wilson design has four ratios giving road speeds of 125, 98, 70 and 42 m.p.h. on the A and B types and 140, 117, 97 and 74 m.p.h. on the Zoller C types. The ratio is selected by the contraction of external brake bands on three epicyclic gear trains. It is a particular feature of the layout that the gear about to be required can be pre-selected by the driver simply by moving a lever mounted beneath the steering wheel. The actual engagement of the gear can then be made at any time by depressing what would normally be the clutch pedal. This gives distinct advantage in driving on some circuits, and foolproof and almost instantaneous changes of gear can be made.

Rear Axle

The E.R.A. is one of the few designs which use a torque tube transmission. A single universal joint is placed behind the gearbox, the propeller shaft being enclosed within a tube which is joined to a spherical bearing which absorbs driving and braking torque and also drives the car, and at the other end to a light alloy bevel housing split on the centre line of the car. Although not forming part of the original specification (except on C types), nearly all the cars running in Formula I have been converted to include a Z.F. Type limited slip differential.

Rear Suspension

Rather short semi-elliptic springs shackled at both ends are mounted on outriggers from the frame.

Front Suspension

On A and B models short semi-elliptic springs are shackled at each end and a rigid front axle beam located by a radius rod is bolted to them. On the C type cars Porsche trailing arms are used with torsion bars running side by side in a tubular cross-member.

Steering Gear

A worm and wheel gear is used and on the C type model the push-pull rod is connected to a bell crank mounted on the nose of the car, to which are fixed two half-track rods joined to the steering arm on the front hub.

Frame

A and B type models have channel type frames with somewhat exiguous cross-members, but the stiffness of the C type frames was increased somewhat by the use of box section, two tubular cross-members being mounted immediately above and behind the radiator with a small diameter tube beneath the driver’s seat and another below the fuel tank.

Brakes

A and B type cars had Girling brakes of mechanical type in which tension rods are used to expand the shoes through the medium of a wedge and rollers. C type cars were fitted with Lockheed hydraulic brakes of two leading shoe type, and a number of earlier models running in Formula I racing have also been converted to full hydraulic brake systems.

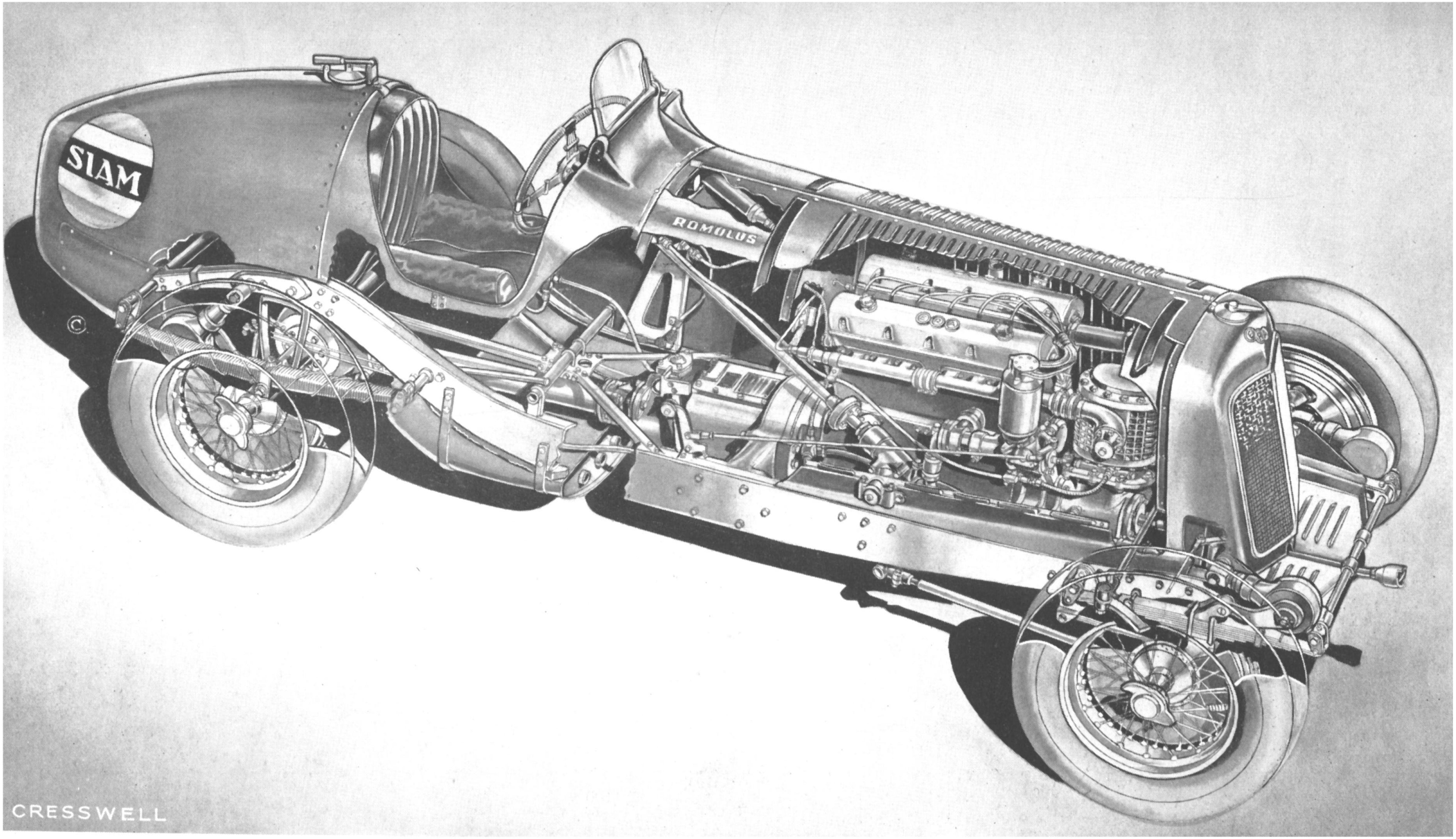


PLATE 1

The B Type I½-litre E.R.A. was one of the most successful racing cars of its class in the period 1934-9 and the car shown here was the most successful B Type made. Features which are clearly shown include the short front and rear springs, light cross bracing to the channel frame and the offsetting of the steering box in relation to the steering wheel. The drawing also shows how the six-cylinder engine had a Roots-type blower mounted vertically on the nose of the crankcase and transmitted power without an intermediate clutch to the gear bands of the Wilson epicyclic gearbox. Torque tube drive was employed for the rear axle.

Body and General Features

When the E.R.A. was originally designed considerable thought was given to performance in sprints and in hill climbs. The improved weight transfer from front to rear and the importance of driver visibility in this class of event were partly responsible for the decision to use a central driving position which was, of necessity, somewhat highly mounted in order to give clearance for the torque tube which moved beneath it. No effort can be seen on the original design to reduce the drag except to keep the cross-sectional area as low as possible in view of the seating position chosen, and the tail is as short as it can be made consistent with enclosing the fuel tank.

Dimensions (C Type)

Wheelbase 8 ft. ; track 4 ft. 4½ in. front, 4 ft. rear.

DEVELOPMENT

Detail refinements in the engine have permitted in some cases a slight increase in engine h.p., which may have gone up to 190 b.h.p. at 7,500 r.p.m. in individual cases. In the main, however, attention has been given to improving the road-holding of the cars, both by the location of improved hydraulic dampers on the beam front axles of the A and B types, and the use of external radius arms to locate the rear axle.

The E Type

It may be appropriate in this section to give some information regarding the E type E.R.A. This was designed in 1938, and was a complete and, as events have proved, not very successful breakaway from the previous models. The basis of the three-bearing crankshaft and an iron crankcase-cum-cylinder block was retained, but the bore was enlarged to 63 mm. and the stroke reduced to 80.5 mm. with a corresponding reduction in piston speed. The iron casting ended on the centre line of the crankshaft and a steel strap was used to retain the centre bearing, a deep light alloy sump replacing the dry sump lubrication arrangements characteristic of the A, B and C models. The C type Zoller compressor was used, mounted on the right-hand side of the crankcase, and a further detail change was the use of studs in place of bolts to join the halves of the big end which embraced a light alloy shell. The cylinder head and valve gear were little changed from previous types and although the connecting rods on this engine were a definite source of weakness, some very satisfactory bench-test figures were recorded, 260 b.h.p. being reached at 7,000 r.p.m., equivalent to 325 b.m.e.p. at a piston speed of 3,650 ft./min. The output per sq. in. of piston area was 8.97 b.h.p.

Immediately behind the clutch a step-down gear was provided so as to lower the propeller and the driver's seat. The four-speed synchro-mesh gearbox was mounted at the rear of the car and bolted on to the bevel box, the drive including a Z.F. differential. A de Dion type rear axle was used with torsion bar rear springs together with a tubular frame, and Porsche type independent front suspension similar to the C type cars.

In respect of general layout and performance factors, there was no reason why E type E.R.A.s (of which three were made) should not have challenged successfully the Continental Formula I models but, unfortunately, the skill exhibited in the detail design fell considerably short of the imagination shown in broad concept, and despite considerable efforts made by the works under new organisation it was not possible to make the car raceworthy in its original form.

MASERATI

INTRODUCTION

The first Maserati racing car, built in 1926, had a 1½-litre straight-eight engine, and in the ensuing thirteen years a car with an engine of this size was always available from the works, which specialised in the sale of racing cars to private owners. The immediately pre-war 4 CL model was derived directly from the 3-litre 8 CL Type which put up some meritorious performances in the Grand Prix racing of 1938-9. The smaller car, which replaced the 1936-8 six-cylinder model, was beaten by the eight-cylinder Alfa Romeo cars in the races in which they jointly competed during 1939, but it was successful in a number of other events and in this year it was, if not the fastest 1½-litre car, certainly *proxime accessit.*

This Type 4 CL had a box-section frame and the front suspension comprised two wishbones of nearly equal length which, as shown in a drawing, were made of C-section plate, the stub axle being supported in spherical bearings. The upper wishbone engaged with a torsion bar running outside and parallel with the frame. A very large oil tank was placed beneath the driver’s seat and, made from a light alloy casting and four-point mounted, this formed a substantial cross bracing to the chassis at this point.

A number of 4 CL Maseratis ran in immediately post-war racing but the type was modified in 1947 and given the nomenclature 4 CLT, the principal change being the use of a tubular chassis. The Type 4 CLT/48, with which these notes are specifically concerned, was introduced in June, 1948, for the San Remo Grand Prix in which it was victorious. It is frequently referred to as the San Remo model and may be externally distinguished from the preceding type by the lower tubular frame members and the coil type, independent front suspension. It should perhaps be noted that this car was introduced after the Maserati brothers had left the company.

CONSTRUCTION

As the Maserati is specifically designed for racing by private owners, it is characterised by a simple and straightforward layout and in some directions (e.g. the use of two cast-iron cylinder blocks) considerations of cost of construction and maintenance have clearly had precedence over the purely technical desirability of highest performance and/or lowest weight.

Engine

Despite the use of four cylinders only, the piston area of the Maserati is but little less than that of rivals with more cylinders, this following from the use of equal bore and stroke so that at 7,500 r.p.m. the piston speed is only 3,840 ft./min. The engine layout is, so to speak, “ old fashioned ” not solely in respect of the number of cylinders employed, for examination shows that traditional layout has been followed in a number of other respects.

The crankcase proper is formed from two magnesium castings of almost equal depth and the three bronze main bearing shells are held in halves in the upper and lower portions of the crankcase. The halves of the crankcase are in turn joined together by long bolts passing through pillars and, as seen in a drawing, transverse webs are used to give additional stiffness to the assembly. A magnesium alloy oil sump closes the base

of the engine, which is notable for exceptional depth despite the use of dry sump lubrication. The crankshaft runs in bronze-backed white metal bearings, the mains and pins being drilled lengthwise to reduce weight, with light alloy plugs inserted to provide oil tightness, the big ends having plain bearings and the babbit being applied directly to the connecting rods. The connecting rods themselves are H-section machined all over, these having replaced the tubular rods which were characteristic of Maserati products for very many years.

The cylinders are formed in pairs from two castings which have open sides to the water jackets (which are later closed by steel plates) and embrace the cylinder heads, each of which contain four valves placed at an included angle of 90 degrees, each inlet and exhaust valve having its own separate port. As each valve has a diameter of 1.575 in. the total inlet valve area of 15.6 in. reaches the remarkable relation to the piston area of 0.525 : 1 and at 260 b.h.p. the flow value is only 16.6 h.p./sq. in.

The valves are closed by coil springs and opened through the medium of followers which replace the inverted pistons used on the earlier cars. Also mounted on the front of the crankcase is the primary blower which is coupled direct to the crankshaft and the smaller second-stage blower (both of the two-lobe Roots type) which lies immediately above it. Both run at engine speed, which accounts for their large bulk in proportion to the delivery ; and they run in opposite directions, the double-choke horizontal Weber carburetter being bolted to the right-hand side of the primary blower, the discharge from the second-stage blower being immediately above it to a large diameter pipe feeding the eight inlet ports. A manifold pressure of 2.6 ata. is used in conjunction with the moderate compression ratio of 6 : 1. The pistons have a strange head shape, in that they are not only domed viewed on the axis of the crankshaft, and have peaks on each side at 90 degrees thereto, the head falling away on each side presumably to give clearance for the valves should they stick in the open position.

The valve timing is simple and conservative, the inlet opening 25 degrees before and the exhaust closing 25 degrees after top dead centre. Similar symmetry is provided with an exhaust opening 55 degrees before and an inlet closing 55 degrees after bottom dead centre.

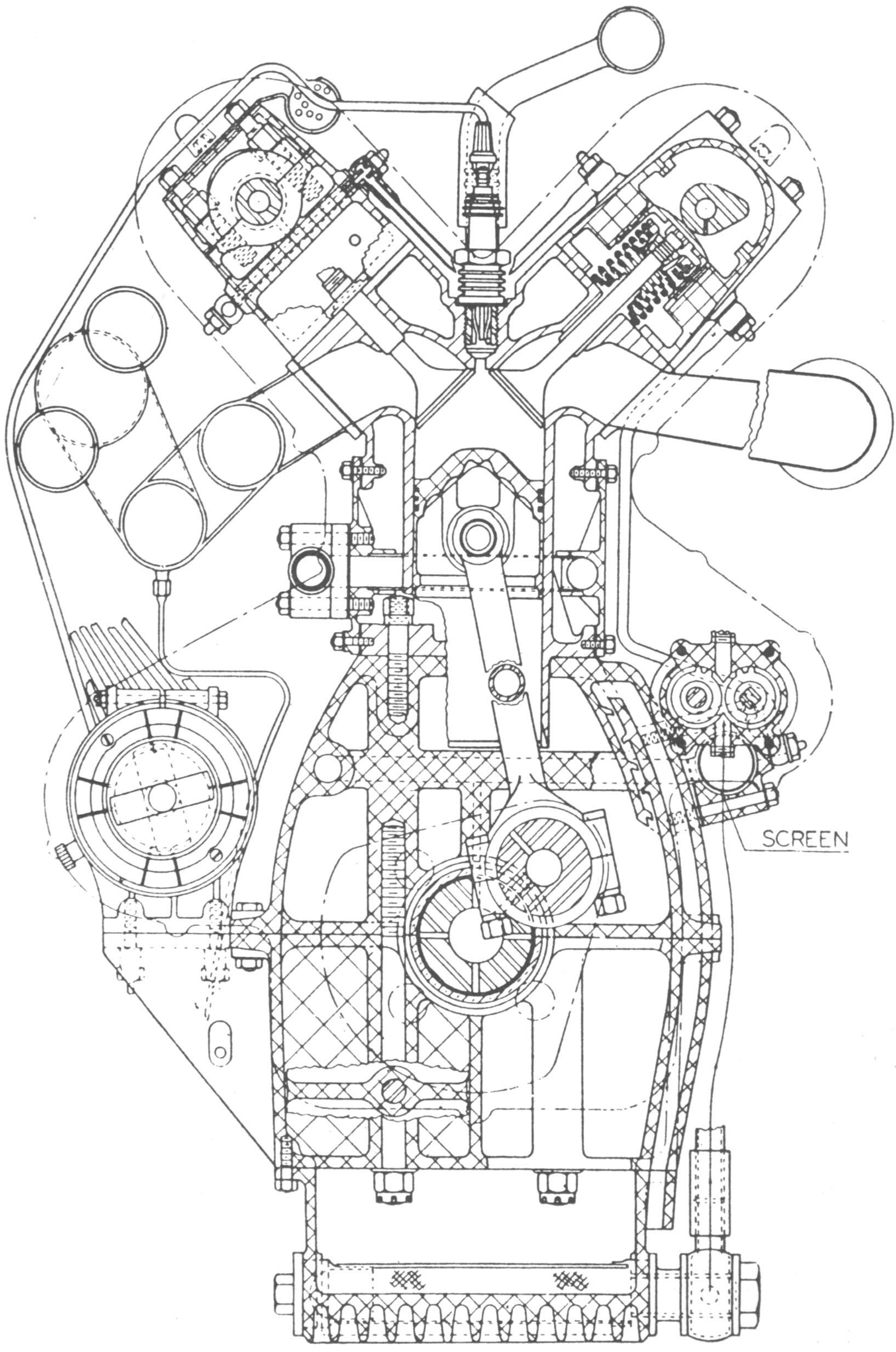
The water pump and magneto are driven in tandem from the front of the crankshaft and lie immediately beneath the inlet pipe and four riser pipes carry the water back to the header tank of the radiator. An oil cooler is provided immediately behind the main radiator core and oil is circulated into a tank placed beneath the driver’s seat, but this is not relied upon, as on the earlier models, to act as a frame stiffener. Ignition is by heavily masked plugs fitted on the centre line of the head.

Gearbox

The four-speed gearbox is bolted to the crankcase and provided with a central ball-type gear lever. The gearbox casing is extensively ribbed and although a variety of ratios is provided the normal stages in relation to the final drive are 1.24 ; 1.69 ; and 2.91 : 1.

Rear Axle

A live rear axle is used with two steel axle tubes bolted on to an alloy casting split on the centre line, which encloses the bevel gears, differential and a step-down gear which lowers the propeller shaft. In the early model cars the propeller shaft was



Although modified both in respect of valve gear (which used rocking fingers) and connecting rod design (H-section), the four-cylinder, 1½-litre Maserati cars had the same dimensions and general construction as the eight-cylinder 3-litre models used in Grand Prix racing in 1938 and 1939, of which the above illustration is a cross-section. (Scale 1 : 4.)

itself enclosed in a torque tube with a spherical joint placed behind the gearbox ; on the 4 CLT 48 an open shaft is employed in conjunction with external radius arms pivoted on to the frame and equal in length to the propeller shaft. The rear axle bevels give choices of 5, 4.6, 4.17 : 1 and 3.41 : 1. On the 4.17 ratio, 7,500 r.p.m. is equivalent to a road speed of 149 m.p.h. on top gear and to 120, 83 and 51 m.p.h. on the three indirect ratios.

Rear Suspension

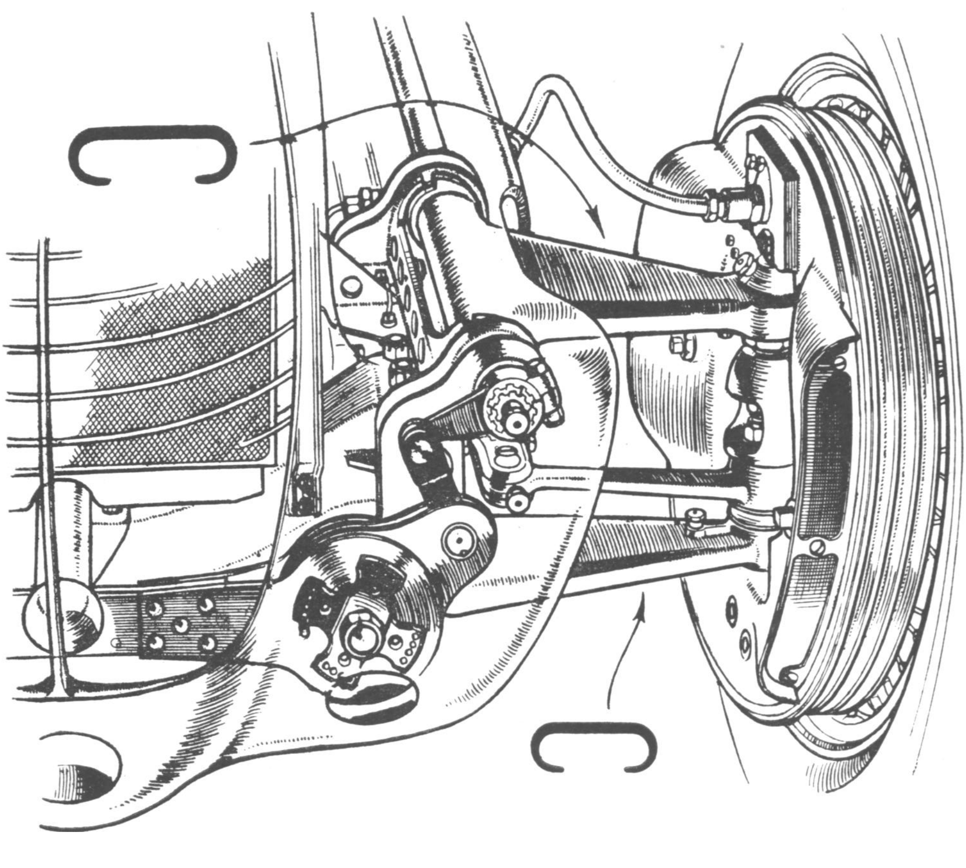
Short quarter-elliptic springs are used at the back of the car, having nine leaves and these are damped by Houdaille vane-type shock absorbers.

Front Suspension

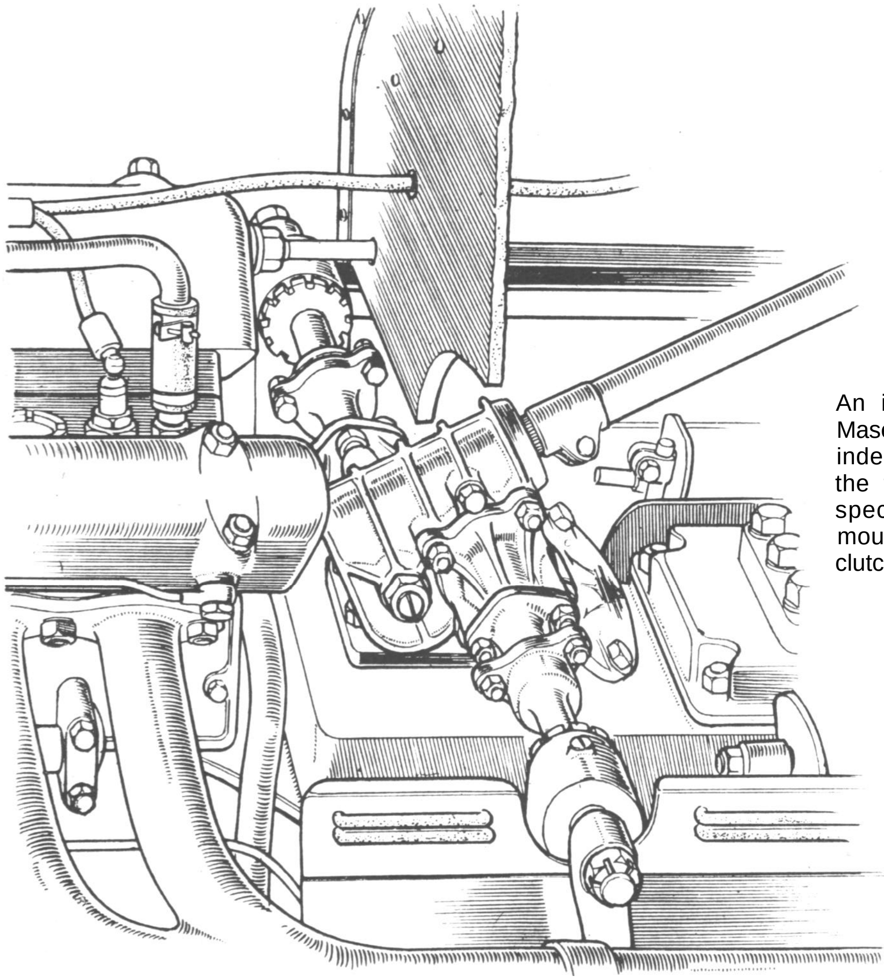
On the 4 CLT 48 model the bottom link of the independent suspension system is of true wishbone form but a single arm is used for top link mounted in very long bearings on each side. A projection of the arm emerges from the front bearing and forms a link with the Houdaille-type damper and the centre of the top arm is developed as a rocker which engages a short open coil spring which acts as the suspension member. The king-pin is mounted between the wishbone arms in which it is supported on spherical bearings.

Steering Gear

A worm and wheel steering box is mounted immediately behind the cylinder block. A shaft extends across the full width of the car carrying two drop arms one on each side. These in turn are linked by push-pull rods to the steering arms so that there is true independent steering of each front wheel without the intervention of a track-rod.



The Type 4 CL Maserati cars used an independent front suspension system in which unequal-length wishbones made out of pressings were joined to a torsion bar running parallel with the frame and embraced (through the medium of ball and socket joints) the front wheel hub and king-pin.



An interesting feature of 1½-litre Maserati cars has been the use of independent steering to each of the front wheels by means of a specially designed steering box mounted immediately above the clutch housing as shown here.

Frame

The side members of the frame are parallel and consist of steel tubes coupled with two large diameter transverse tubes at the extreme nose and adjacent to the rear spring mountings. Stiffness is also increased by two smaller diameter cross-tubes placed just ahead and just behind the crankcase and by two tubes placed in the form of a cross which join the main frame at a point level with the universal joint at the front end, and as near as possible to the rear axle at the back end. The tubes taper inwards and pass below the rear axle, two parallel bars projecting to the extreme rear of the car and giving a support for the fuel tank.

Brakes

Hydraulic brakes are used, the drums containing stiff, light alloy shoes, which do not work on the two leading shoe principle.

Body and General Features

The driver's seat is centrally placed and has to be somewhat high to accommodate the moving propeller shaft, despite the fact that this is lowered by the spur wheels contained in the nose of the axle casing. The radiator cowl has a deep opening and every effort has been made to keep the car down to the minimum dimensions possible in the light of the chassis construction.

Dimensions

Wheelbase 8 ft. 2½ in. ; front track 3 ft. 11½ in. ; rear track 4 ft. 1½ in.

DEVELOPMENT

During 1949 and 1950 efforts were made by some private owners to increase the output of the engine by raising the supercharge pressure, and figures as high as 280 h.p. have been mentioned. An even more ambitious programme was embarked upon by the Scuderia Milano under the direction of Prof. Mario Speluzzi. This embraced revised cylinder block castings giving improved water circulation around the exhaust valves; a built-up crankshaft permitting one-piece big ends; larger blowers and manifolds, giving increased supercharge pressures; and changes in the steering gear providing a single arm at the centre of the car to which two equal-length track-rods could be attached. Unfortunately, although these cars were undoubtedly faster than the standard models, they did not achieve the reliability required to keep them in the forefront of Formula I racing in 1950-1.

CHAPTER FOUR

Post-War Projects and Practice

IT is somewhat astonishing that nearly all the post-war victories in Formula I were secured by pre-war designs and not until 1951 was the basically 1938 1½-litre Alfa Romeo fairly beaten.

This effective racing life of thirteen years is most remarkable, for even taking into account the break caused by war years it is, in the scale of time, the equivalent of a 1908 Grand Prix car being as fast as a 1921 type, or, eliminating the war years, of a 1933 design being unbeaten until 1939.

This long run of success was not, however, wholly to be accounted for by the design of the Alfa Romeo. Political and commercial factors also played a prominent part in delaying the arrival of more modern designs with higher performance. In Italy lack of funds prevented Maserati from doing more than modify steadily the basic 1938 type and as this was originally inferior in performance to the Alfa Romeo it is only natural that it continued to exhibit this inferiority in all subsequent years. Whereas, however, Maserati won many international races when Alfa Romeo were not present, one of the most interesting post-war products, the Porsche-designed Cisitalia, was never, owing to lack of funds, able to make an appearance on a European circuit, the only completed car being shipped to Argentina, where it has made one brief and unsuccessful appearance. This is greatly to be regretted as, if developed, this horizontally opposed, twelve-cylinder, four-wheel drive car might well have shattered many circuit records.

Ferrari, by contrast, produced a number of original, yet practical, designs of considerable merit, but the efforts of a dozen or so designers and a mere 200 workpeople were concentrated first upon Formula II and sports-car racing. Not until 1949 was Ing. Aurelio Lampredi given instructions which resulted in the production of the 4½-litre Ferrari which proved to be the only serious rival to Alfa Romeo.

In France a series of political and economic crises prevented the development of any 1½-litre supercharged racing cars, although one such, the Arsenal CTA, was designed and built with state funds. This needed a great deal of development, for which further support was not forthcoming.

Anthony Lago, working as an exponent of private enterprise, produced a considerable number of six-cylinder 4½-litre Talbot cars, but although these ran with commendable reliability they were never able to challenge the Italians in power and speed.

Not until 1951 were German products considered eligible for Grand Prix racing and, as explained elsewhere, by this time the only company seriously interested in Formula I–Mercedes-Benz–decided that they would await the introduction of the 1954 formula. In England great public interest was concentrated upon the B.R.M., plans for which were laid in 1947 with a car first shown to the public at the end of 1949. Theoretically capable of beating not only any alternative Formula I type but also any pre-war car, this complicated, somewhat heavy, and unconventionally supercharged

sixteen-cylinder model depended for success upon a strong and uniform development policy, rigorous, even destructive, testing, and ample funds. Unfortunately, none of these were forthcoming, and when at last in 1953 the cars showed that theoretical promise could be equated with practical performance Formula I was extinct so far as Grand Prix racing was concerned.

To sum up, with the exception of the 4½-litre Ferrari, the post-war designs of Formula I achieved no great success. This notwithstanding, they embodied many features of technical interest as may be seen from the brief descriptions which now ensue.

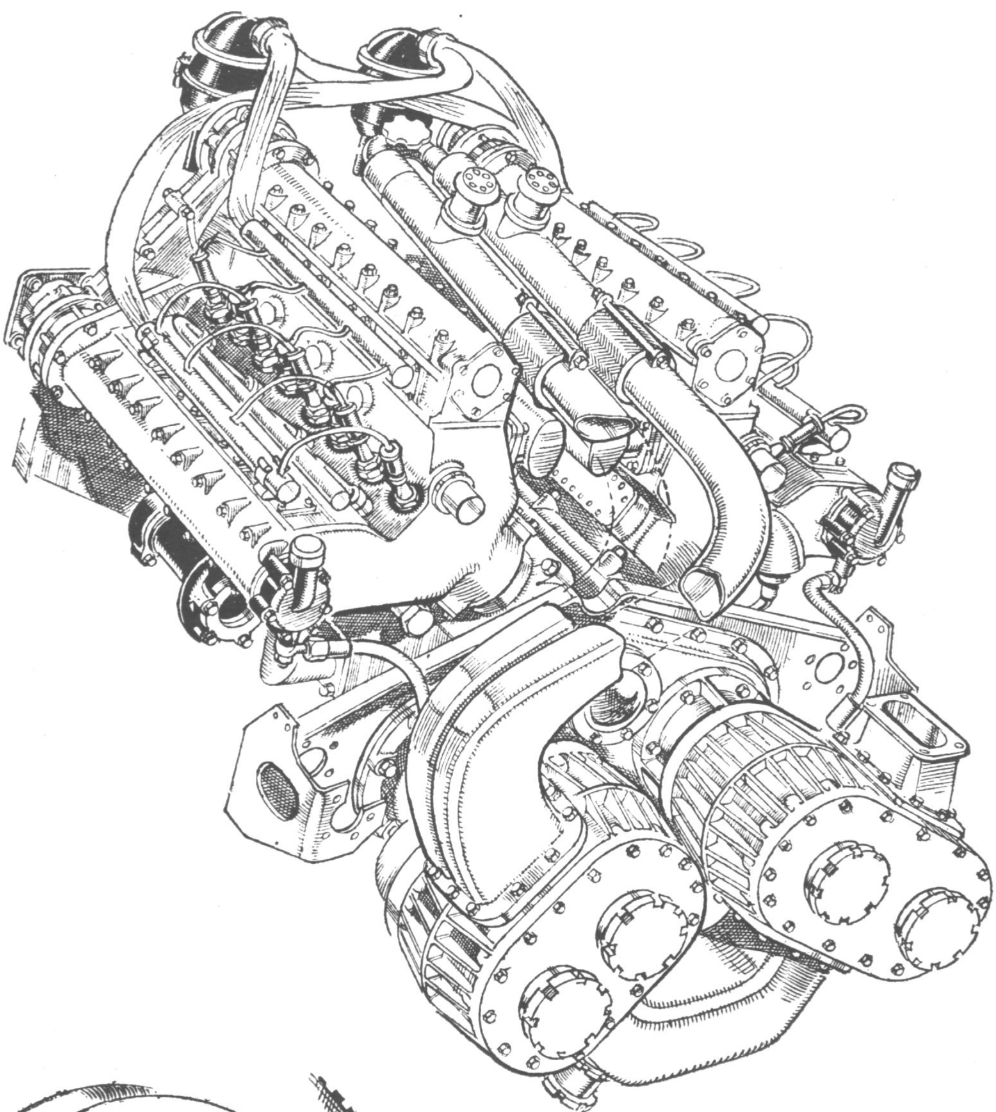
ARSENAL CTA

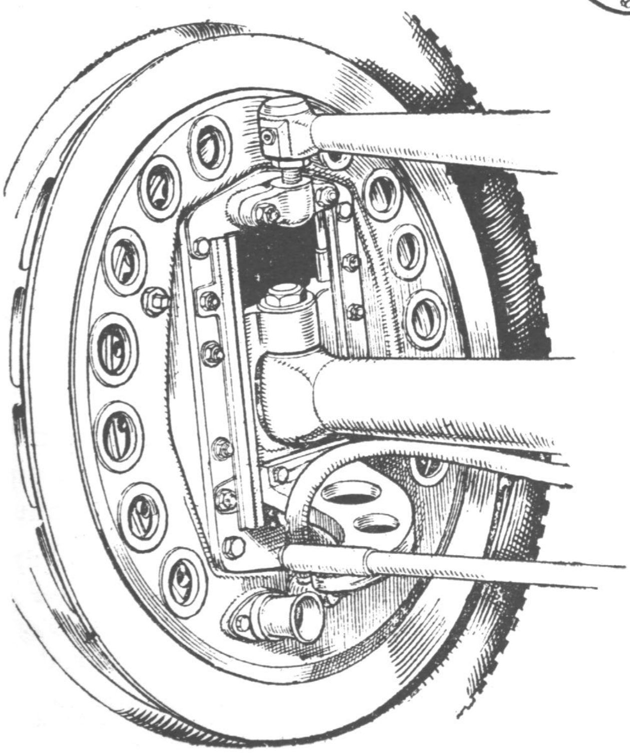
In the only entirely post-war design produced in France, the Arsenal C.T.A., the theoretical merits of the sixteen-cylinder type were passed. over. The engine was designed by Monsieur Lory and bears in many details a close relationship to his designs between 1924 and 1927. Like the 1924-5 2-litre Delages he chose to use a Vee-type engine ; like the 1926-7 l½-litre he settled upon eight cylinders. Whereas, however, the straight-eight Delages had a bore and stroke of 55.8 mm. x 76 mm. and an S : B ratio of 1.36 : 1, the C.T.A. designed ten years later had a bore and stroke of 60 mm. x 65 mm. and an S : B ratio of 1.08 : 1. As a consequence, the engine had a piston area of 35 sq. in. which may be compared with 31 sq. in. for the 1927 l½-litre type and 38.7 sq. in. for the 1925 2-litre Delage.

The two iron cylinder blocks retained the usual Lory features of integral cylinder heads having two overhead valves inclined at 100 degrees, also steel plates forming the sides of the water jacket so that the castings could be thoroughly cleaned before the engine was assembled and run. The layout of the valve covers was also highly reminiscent of Delage practice, but the drive to the camshafts (through trains of gears) was placed at the back end of the crankshaft and, as a major change, ignition was by two sparking plugs placed on the centre line of each cylinder head.

As can be seen from a transverse view of the engine reproduced in the last chapter of this book, each cylinder block was bolted on a light alloy crankcase with an included angle of 90 degrees between the axes. The crankcase was carried 6 in. below the centre line of the crankshaft and stiffened by through-bolts running beneath each of the five roller main bearings. These had split gauges and were located by caps deeply spigoted and held up on to the upper half of the case by set bolts. The shaft itself was 52 mm. diameter and the crank-pins were 42 mm. diameter each supporting connecting rods using roller tracks 15 mm. wide offset by 25 mm. The plain gudgeon-pin is 23 mm. diameter and the rod 140 mm. between centres or stroke by 2.15.

A two-section oil pump was located at the back end of the crankcase to provide for both scavenge and oil delivery, the latter being in the first place to external pipes and jets running to each main bearing, the side of the crank-webs carrying annular collectors so as to feed the hollow crank-pins and big ends by centrifugal force. At the top end of the engine the inlet valve with a diameter O.D. 37 mm. was slightly larger than the exhaust which was of 34 mm. giving valve areas of 13.3 and 10.3 sq. in. respectively. Each valve was closed by three coil springs with a follower introduced between the cam and the valve head. There was no internal cooling of the exhaust valve, but water was delivered from two pumps to an internal conduit placed between





Although never run in a Grand Prix, the 1½-litre Arsenal C.T.A. Formula I car was an interesting example of immediate post-war design. The engine was laid out by Lory, and although of V.8 formation, shows in general layout a marked resemblance to the 1927 1½-litre Delage straight-eight of the same capacity. With two-stage super-charging with Roots blowers some 275 h.p. was realised from this power unit. The detail drawing (left) shows the unusual suspension system with the wheel sup-ported on sliding blocks. This was not a successful arrangement.

the exhaust ports. From this a directed flow of water was spread around the seating of the valve and the base locating the valve guide.

Two Roots blowers giving two stages of boost were driven at three-quarters engine speed from the nose of the crankshaft, this modest rate presumably being chosen in order to lessen the turbulence around the rotor tips and indicating that the designer had in mind a very high crankshaft speed. Drawn from a downdraught double-choke four-float Solex carburetter, the mixture was supplied at 30 lb. boost (3 ata.) and, with this boost pressure, well over the 300 b.h.p. might well have been expected from the engine in its fully developed form. In fact, outputs of over 270 h.p. were attained on the test-bed, but after a disastrous first appearance in the French Grand Prix at Lyons in 1947 (in which the transmission succumbed on the starting line) the car failed to run in any subsequent event, although it appeared in practice for the French Grand Prix of 1948.

Whatever merits the engine may have had were obscured by various transmission and chassis troubles. The power unit was placed centrally in the frame with the crankshaft inclined downwards at 8 degrees, the propeller shaft passing beneath the central driving seat and being coupled to a double reduction gear placed ahead of the combined gear and bevel box housing which was attached to the tubular frame. Open halfshafts took the drive to the rear wheels, which were suspended on torsion bar springs and located by slides in a manner familiar to those who have studied locomotive design. A variation of this strange, and, as it turned out, unhappy, concept appeared at the front end of the car and it should be mentioned in fairness that Monsieur Lory was not responsible for the chassis layout.

The car as a whole was built on a national basis, using state funds, by the Centre d'Etude Technique de 1'Automobile et du Cycle.

CISITALIA: PORSCHE TYPE 360

Although no less disappointing than the C.T.A., in that it was never seen in action, the twelve-cylinder rear-engined Cisitalia was a far more serious contribution to racing car design than the French project. The firm Cisitalia was founded in 1946 by Dusio in Turin with the initial objective of building a batch of fifty single-seater racing cars constructed mainly from Fiat parts. The idea was that these would make a class of racing cars in which, as every vehicle would have the same performance, the result would be a true reflex of the driver's skill. Or, to put the alternative viewpoint in the words of Dr. Alessio of Alfa Romeo. " Motor racing would degenerate into a mere struggle between drivers."

The 1,100 cc. racing cars were in due course followed by two-seater 1.3-litre production models carrying closed bodywork, and still further to raise the prestige of the company Dusio decided in 1947 to sponsor a brand new Formula I car produced to the very highest standards of design and performance. To this end he signed an agreement with the post-war organisation, then situate at Gmund in Austria, headed by Dr. Ing. h.c. Ferdinand Porsche. Working under Dr. Porsche's instructions, chief designer Raube and his assistants thereupon produced the drawings of the " Porsche Type 360," and Professor Dr. Ing. Eberan von Eberhorst went to Turin to act as a liaison officer and to develop the car in detail.

From a theoretical viewpoint the Type 360 Porsche is certainly the most interesting post-war racing car-indeed it is one of the most ingenious design studies in the whole history of motor racing. With a bore and stroke of 56 mm. x 51 mm. and twelve opposed cylinders, a piston area of 45.7 sq. in. is provided (i.e. slightly less than the figure given by the sixteen-cylinder B.R.M.) ; so, assuming that 12,000 r.p.m. could be maintained with reliability, and on a basis of 400 lb./sq. in. b.m.e.p., some 550 h.p. should have been attained with a fully developed engine.

CONSTRUCTION

The notes which follow have been made possible by the kind co-operation of Dipl.-Ing. Ferry Porsche, and Prof. Dr. Ing. R. E. van Eberhorst, who have supplied full working drawings and notes on the development of this project.

Engine

The horizontally opposed twelve-cylinder engine is placed directly behind the driver's seat and the vertically split light alloy crankcase extends outwards to form the water jackets. Individual cylinder liners in direct contact with the water are inserted and are sealed by light alloy detachable cylinder heads which are cast in one piece for each block. Each head carries two valves at an included angle of 90 degrees which seat direct, the inlet valve having an o.d. of 35 mm. giving a total inlet valve area of 17.9 sq. in. This is slightly greater than the area available on the 1939 3-litre Auto Unions and in accord with a projected output of 500 b.h.p.

The valves are opened by two camshafts for each bank through the medium of followers and a single 18 mm. plug is used set well back and with a 6 mm. passage connecting the points to the combustion chamber.

The bore and stroke give a piston area of 45.7 sq. in. and the seven-bearing Hirth type crankshaft has the remarkably large diameter of 54 mm., which is nearly equal to the bore itself. Even the gudgeon-pin is 18 mm. diameter, or one-third of the

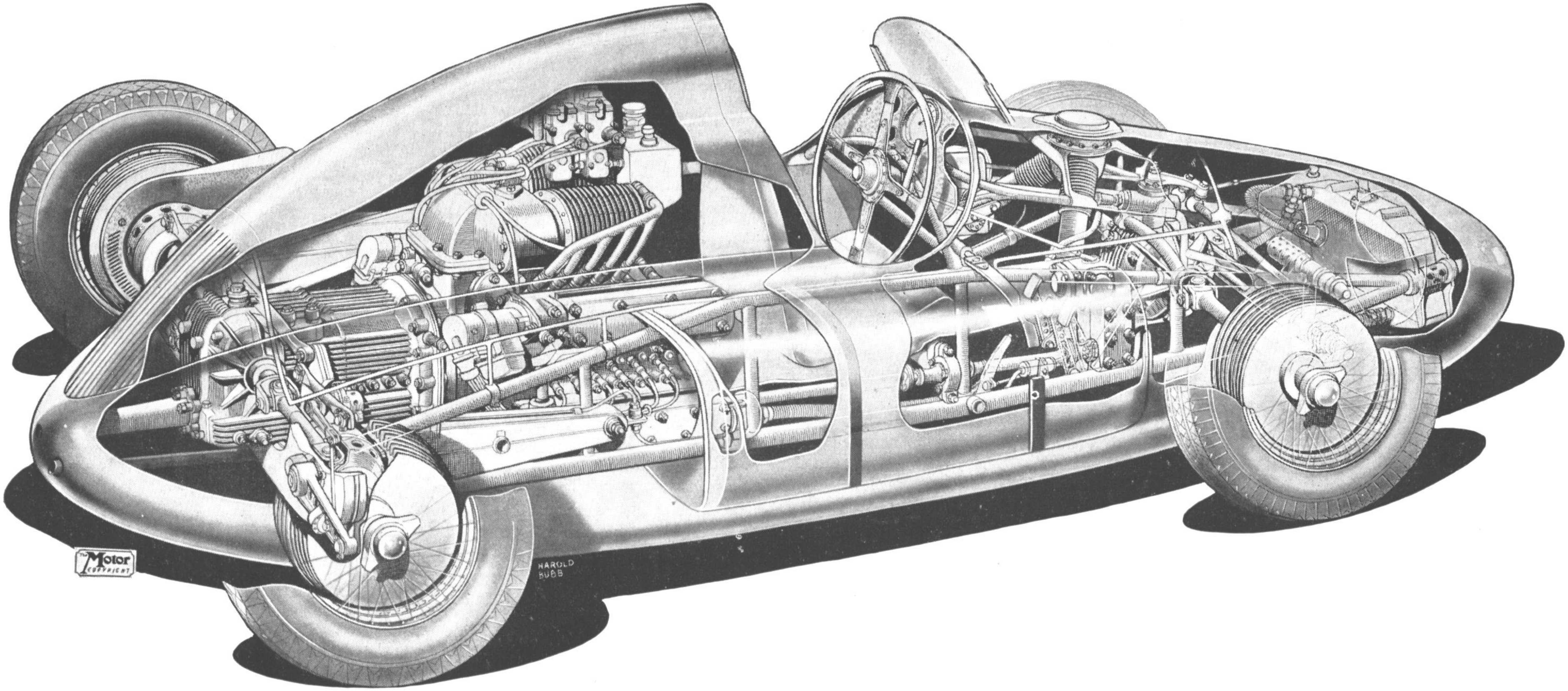
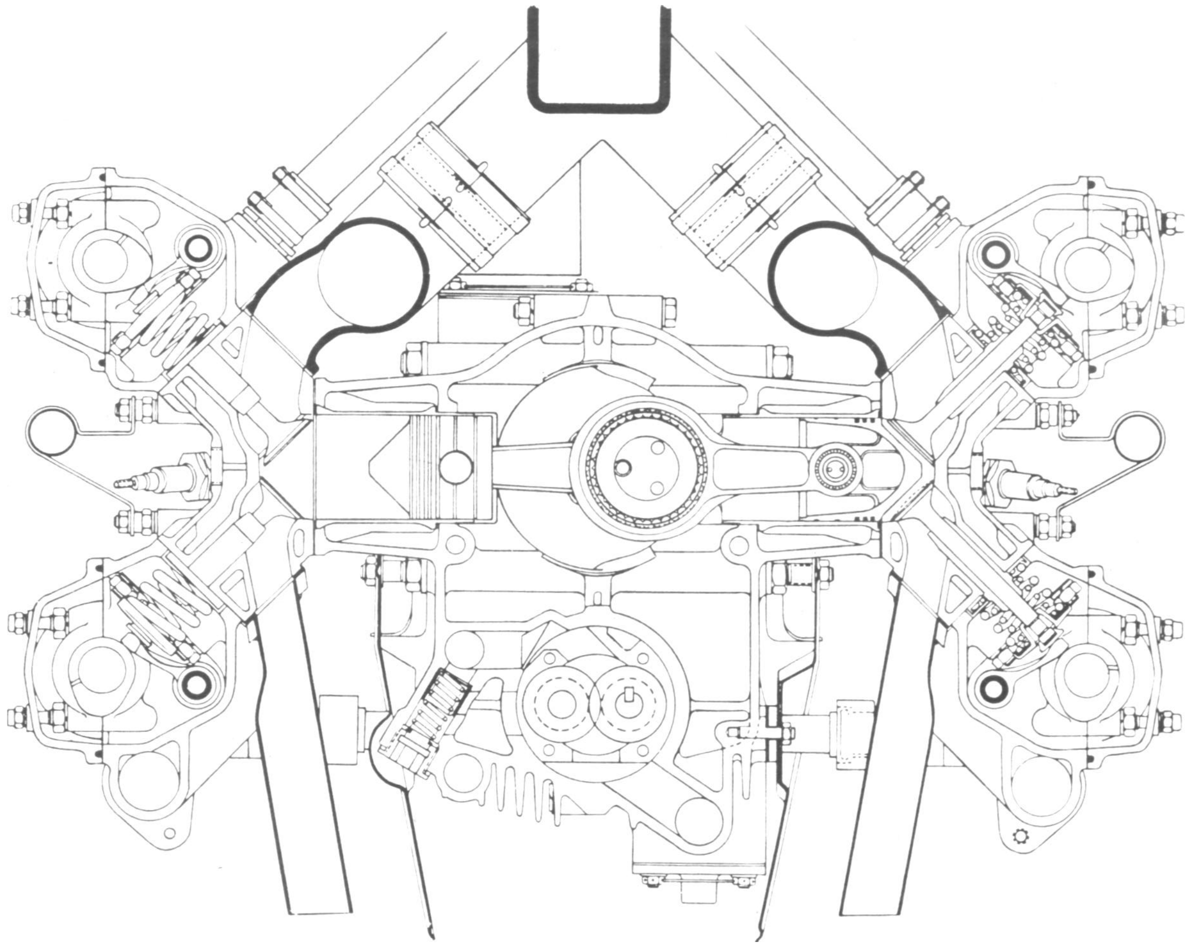


PLATE 11

The 1½-litre Fiat-12 Cisitalia was designed by Dr. Porsche and his team of engineers, Although it has never appeared in European competition the design was of striking originality and one car was assembled and shipped to Argentina. As can he seen from this drawing, a space type frame supports a rear-mounted engine driving a constant-mesh five-speed gearbox and supercharged by two vane type compressors. Rear suspension embodied double-jointed halfshafts, the wheels being supported by transverse radius arms and a longitudinal torque arm. An unique,feature of the car was the provision for four-wheel drive through a forward running propeller shaft connecting to a front bevel and differential box which could be coupled up at the will of the driver.



This 1 : 4 scale drawing of the Porsche-designed Cisitalia engine reveals the great stiffness of the crank-connecting rod-piston assembly, and the interesting use of a detachable cylinder head with direct seating for both inlet and exhaust valves. The cylinder liners are individually detachable sleeves.

cylinder bore, and although the connecting rods which are one-piece types are conventionally proportioned with a length between centres of crank radius x 4 they are absolutely only 4 in. long. In consequence, that section of the rod lying above the big end radii and below the gudgeon-pin fillet is little more than 1¾ in. long, giving an exceptionally stiff assembly.

Partly by reason of wet cylinder liners the cylinder centres are only 69 mm. apart so that the overall length of the engine, excluding the clutch, is only 22 in.

This compact layout is greatly assisted by the manifolding arrangement in which the exhaust ports discharge directly downwards, the ingoing charge being fed to the inlet ports from two vane type blowers mounted above the crankcase. These are of single-stage type with internal compression having ported drums to separate the blades from the light alloy casing. Fuel is supplied through downdraught carburettors which project into the head fairing provided for the driver.

On a basis of 10 h.p. per sq. in. of piston area this engine should have produced nearly 450 b.h.p. at 10,500 r.p.m., this being the equivalent of 370 b.m.e.p. at a piston speed of 3,350 ft./min.

It was anticipated that this car would weigh not more than 2,200 lb. on the starting line and the corresponding figure of 450 h.p./ton is about 10 per cent higher than that achieved in 1939 and little short of that obtained in 1937. The knowledge

that the full power of these cars could not usefully be applied owing to wheelspin led to the decision that on the Porsche Type 360 the engine should be connected to both front and rear wheels.

Transmission

Power is transmitted through a 7½-in. diameter multi-plate clutch to a five-speed gearbox mounted somewhat surprisingly between the engine and the bevel box. The gearcase is split vertically on the centre line, a necessity in view of the novel gear engagement system employed.

A pair of constant-mesh wheels takes the drive from the clutch shaft down to a shaft lying on a lower plane. Surrounding this lower shaft are five gear wheels in constant mesh with corresponding gears fixed to the upper shaft which drives the bevel pinion. The lower gears are each separately mounted on a ball bearing with the lower drive shaft running freely inside them, and by moving a sleeve horizontally in relation to the lower train of gears successive ratios can be picked up by external serrations on the sleeve engaging with internal splines on the gears.

This gives an exceptionally compact layout but, in effect, a quadrant gear change in which a change from fifth to second speed demands the momentary engagement of the fourth and third ratios.

An orthodox bevel drive and Z-F differential transmits power to the rear wheels through the medium of open shafts each with two Hooke type joints.

A spur type gear engaging with the lower gear shaft transmits power to a two-piece open propeller shaft (running 7½ in. below the hub centres) forward to a train of three gears and a bevel box at the front of the car. This drive could be brought in at will by means of a dog clutch and a lever placed below the steering column and the open halfshafts driving the front wheels have double Hooke joints at the outer end to give constant velocity, normal Hooke type joints being used inboard.

Rear Suspension

The 1934-37 Auto Union A-C type cars for which Dr. Porsche was responsible had swing axles and the 1938-9 D type designs, influenced by von Eberhorst, were fitted with de Dion rear axle layout. The Porsche Type 360 used neither, the rear wheels being located longitudinally by fabricated radius arms 31 in. between centres splayed out at 9 degrees. The hubs were connected to the frame by equal length (8.7 in.) arms on each side, a third arm being used for the hydraulic damper.

The car is supported by two rear torsion bars 0.65 in. diameter and with a free length of 20 in.

Front Suspension

A conventional Porsche layout with trailing arms on each side carrying the wheels on ball joints and connected to transverse torsion bars carried in the lower cross-member of the frame.

Steering Gear

A Porsche steering box is mounted high up on the frame, the drop arm carrying two ball joints connecting with the swinging half-trackrods.

Frame

As on the immediately post-war 1,100 c.c. Cisitalias the design embraced a space type multi-tubular frame, the main tubes being 1.36 in. diameter. The structure measures 132 in. from end to end, the main tubes in the centre section being separated by 16½ in.

Brakes

Four leading shoes are fitted within outboard brakes having an external diameter of 17¼ in. with the shoes measuring 13½ in. diameter and 2¼ in. wide. Each friction lining subtends at an angle of 75 degrees and by using cranks and push-rods the four shoes are expanded by two cylinders. A lining area of 320 sq. in. was available.

Body and General Features

As the whole of the tail of the Cisitalia is occupied by the engine and transmission aggregate side-tanks were a virtual necessity more especially as the squab of the driver's seat is slightly nearer the rear axle than the front. A single filler is provided for the tanks just ahead of the windscreen and the tanks themselves are designed in some degree to act as fairings behind the front wheels.

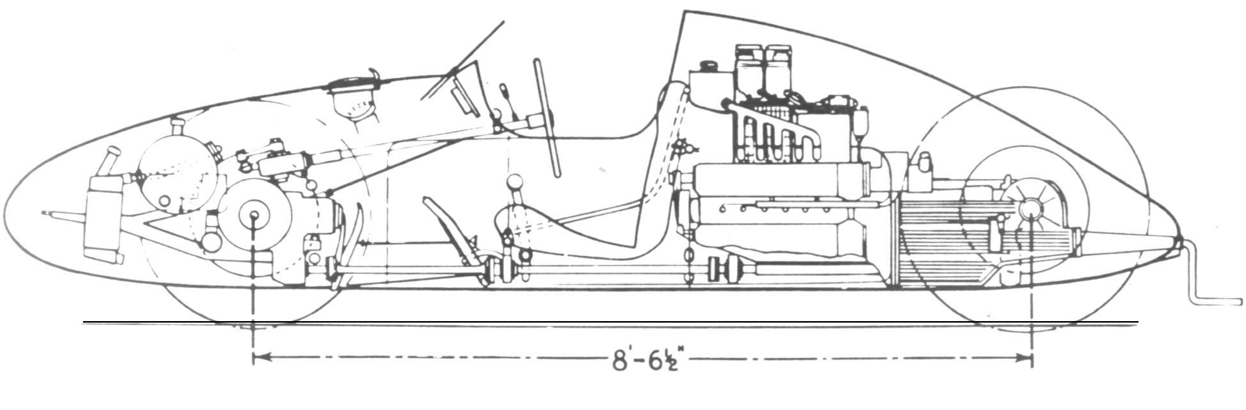
The relatively long nose of the vehicle is sharply swept down to embrace an oil tank for the dry sump engine and a radiator core mounted at approximately hub level. At the back of the car an exceptionally high headrest is a dominant feature dictated in some measure by the necessity to place the driver's seat above the central propellor shaft.

Dimensions of 1.5-litre Cisitalia

Wheelbase 8 ft. 6½ in.; front track 4ft. 3in.; rear track 4ft. 2in.; overall height 3 ft. 9 in.

The gear train layout of the Cisitalia, a point of particular interest being the compactness of the five gear trains achieved at the expense of a selection arrangement which made it necessary for the gears to be engaged consecutively.

This 1 : 25 scale drawing shows the general layout of the Porsche Type 360 designed for the Cisitalia company. The compactness of the engine and gearbox unit can be observed, also the forward drive arrangement and the deep headrest which embraces the down-draught carburetters.



FERRARI 1.5-LITRE

In the decade before World War II, Enzo Ferrari organised the Scuderia Ferrari which, with headquarters at Modena, engaged in the business of racing cars and motor cycles as a commercial proposition. In some years, the Scuderia acted, so to speak, as the racing agents of Alfa Romeo, and in 1940 Ferrari entered the world of automobile manufacturers under his own name with a sports car having an eight-cylinder engine based upon four-cylinder Fiat parts.

At the end of the war he secured from Alfa Romeo the services of Ing. Colombo and a number of the Alfa Romeo development engineers, such as Bazzi, whose experience dated back to the phase of the 1924 P.2 supercharged Grand Prix cars.

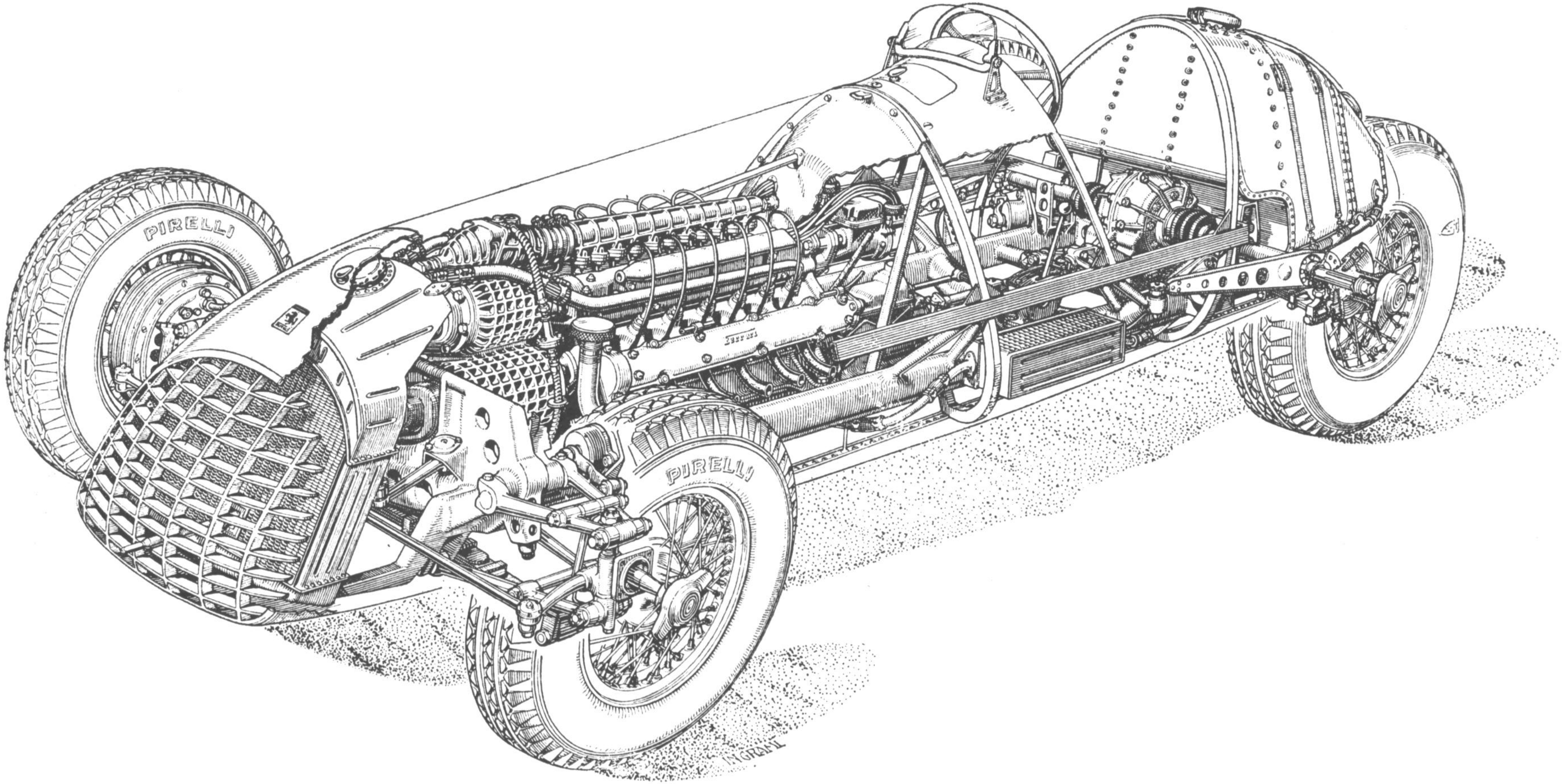
In February, 1947, Ferrari announced a l½-litre unsupercharged sports car having a V.12 cylinder engine developing 118 h.p., fitted into an oval tube frame with wishbone type independent front suspension coupled to a low-mounted transverse leaf spring. A live rear axle was supported on semi-elliptic springs and a five-speed gearbox with an indirect overdrive was bolted to the clutch housing. This model formed the basis of the l½-litre racing car which was introduced for the Italian Grand Prix at Turin late in 1948 and, in the absence of Alfa Romeo, this was the most successful car in the Grandes Epreuves of 1949.

Presentation of the ensuing facts has been greatly assisted by statistics provided by the manufacturers, which make it possible to provide reasonably detailed information regarding the post-war Ferrari racing cars.

Engine

The Ferrari is remarkable for being the first car since 1907 to compete in the Grandes Epreuves with an engine having a larger bore than stroke. The very small absolute stroke and large piston area gave this model an inherent advantage over any rival l½-litre supercharged model (with the exception of the B.R.M.) for the exceptional piston area (44 sq. in.) makes 10,000 r.p.m. attainable without exceeding 3,500 ft./min. piston speed. As run in 1949, however, the maximum engine speed was only 7,500 r.p.m. and with a comparatively modest figure for b.m.e.p. the engine output was no greater than that achieved by cars with considerably fewer cylinders and substantially lower piston area.

The main engine casting is in light alloy and contains the supports for a seven-bearing crankshaft and the water jackets for the twelve inserted wet liners which are grouped in two banks of six at an included angle of 60 degrees. These liners have a flange at their base to provide a water seal, and are closed at their top end by an aluminium-silicon cylinder head (one per bank), each combustion space containing two valves inclined at an included angle of 60 degrees. The inlet valve has a very slightly greater outside diameter than the exhaust valve (1.26 in. as compared with 1.18 in.) and the valve area is therefore 34 per cent of the piston area, the flow value of 15.1 h.p./sq. in. being somewhat low in relation to the manifold pressure. Each valve is closed by a pair of hairpin valve springs lying in a fore and aft plane and opened by a rocker from a single overhead camshaft lying above the centre of the head. The sparking plugs are inserted into the inlet side of the head, i.e. facing inwards into the vee of the cylinder block, and a single Roots type blower running at 1.22 times engine speed is mounted



The chassis and running gear of the 1949-50 1½-litre two-stage supercharged twelve-cylinder Ferrari resemble closely the layout used for the preceding Formula I and II models with single stage, single camshaft 1½-litre engines,or unsupercharged 2-litre engines, and the subsequent unsupercharged 3.3, 4.5 and 2-litre models. The car as shown was, in the absence of the Alfa Romeo, the fastest car of 1949, but was subsequently superseded by the unsupercharged models which had also de Dion rear axles in place of the swing axle shown here.

at the front of the engine discharging into a central manifold and inspiring from a single horizontal Weber carburetter. The camshafts are also used to drive two Marelli magnetos.

A moderate compression ratio of 6.5 : 1 is provided by the slightly domed pistons and the connecting rods are placed side by side on the crank-pin, which is of 1.77 in. diameter. The design of the big ends is interesting in that the division is made vertically, so that the bottom half of the rod may be withdrawn upwards through the cylinder bores if necessary. The crankshaft is heavily counter-balanced and a gear-type pump mounted at the front of the engine feeds into the end of each crankshaft and thence directly through internal passages to the big ends. The main bearings (of 2.313 in. diameter) are separately supplied with oil and this scheme has the particular merit that changes in main-bearing clearances do not affect the oil feed to the big ends, or vice versa:, The weight of the engine with clutch is 430 lb.

Gearbox

A five-speed gearbox is provided bolted direct to the clutch housing, all the gears being in constant mesh and of helical pinion type.

Rear Axle

An open propeller shaft transmits drive to a fixed bevel box, an intermediate gear being used so that the propeller shaft line is considerably below the centre line of the rear halfshafts.

Rear Suspension

The swing axle principle is used for the rear wheel suspension so that the exposed halfshafts are fitted with inboard joints only, whilst a single radius arm is inclined inwards from the hub to a pivot point on the frame. A single transverse leaf spring runs behind and is mounted somewhat below the halfshafts the length of the master leaf being approximately 36 in.

Front Suspension

A transverse spring having a master leaf 38 in. long is mounted beneath the frame in front and connects through levers to a system of unequal-length wishbones which give individual suspension to each front wheel. Both front and rear wheels are damped by Houdaille vane type hydraulic shock absorbers.

Steering Gear

A worm and wheel mechanism mounted at the extreme front on the right-hand side of the frame transmits motion to a central cross-rod, to which two equal-length swinging track-rods are joined, these being mounted ahead of the front wheel centres.

Frame

An oval tube frame is used having a depth of 3.65 in. and a wall thickness of 0.10 in. Large tubular cross-members are placed at the rear end of the frame just ahead of the rear axle housing ; beneath the driver's seat ; and at the extreme front of the car, where additional reinforcement is provided by a transverse plate extending from one side of the frame to the other. In addition, the scuttle is built up with two hoop-shaped members which are welded to the frame to give additional support in the centre section,

Brakes

Hydraulic brakes are used, the front drums being 14 in. diameter and 2 in. wide, and the rear 12 in. diameter and 2.35 in. wide.

Body, General Features, and plates on the twin-camshaft model

The driver is mounted centrally, and the whole car has an exceptionally compact appearance derived from its remarkably short wheelbase. This in turn, however, resulted in a fair amount of overhang both at the front for the radiator cowling and at the rear for the 31-gallon fuel tank.

The combination of swing axle with very short wheelbase gave this model rather pronounced oversteering qualities and in the Formula II cars raced during 1949 the wheelbase was extended by 7 in. This lengthened chassis was also used for the double-camshaft version of the car which also had two-stage supercharging. Although this model won the European Grand Prix of 1949 and achieved two second places in the course of four appearances in 1950, from June, 1950, onwards attention of the works has been concentrated upon the 4½-litre model which is described separately.

Dimensions of 1.5-litre single-stage Ferrari

Wheelbase 7 ft. 1 in. or 7 ft. 8 in. ; track 4 ft. 2½ in.

SIMCA-GORDINI

Although unable (between 1947 and 1951) to secure a place in any of the Grandes Epreuves, the cars built by Amedée Gordini using Simca parts have had certain successes in " classic events " and some notes on their design and construction are therefore justified.

Before 1939 the Equipe Gordini specialised in modifying the French Simca car (which in turn was a synonym for a Fiat built under licence) for sports-car races. Immediately after the war a 1.1-litre single-seater car was produced and gave a good account of itself in a number of minor events which were not run strictly to Formula I limits. Between 1948 and 1949 the swept volume in the engine was enlarged firstly to 1,220 c.c. and then to 1,430 c.c., but the basic Fiat engine design with three-bearing crankshaft and a single camshaft operating in-line overhead valves through push-rods and rockers was retained. Developing 65 b.h.p. in 1.1-litre form, the power unit was installed in a tubular frame, Fiat type front suspension units being employed, and a normal rear axle located by links and sprung with torsion bars. The subsequent development of this engine led to an inclined valve cylinder head with cross push-rods worked from the crankcase-mounted single camshaft. In 1950 the car was still further modified.

Engine

The 1951 Formula I engine used the 1950 type cylinder block, which is an iron casting in one with the crankcase giving support to five main bearings. The engine has a bore and stroke of 78 mm. by 78 mm. and a capacity of 1,491 c.c., the bores themselves being formed from inserted liners of nickel chrome molybdenum alloy. The new light alloy cylinder head of the 1951 cars was supplemented by two overhead camshafts driven by a train of gears from the nose of the crankshaft. These gears also connect with a Wade Roots type blower projecting forwards and receiving mixture from a large horizontal Solex carburetter.

The Type RL 15 Wade has a swept volume of 1.5 litres per revolution and is geared to run at 1.45 times engine speed at a crank speed of 7,000 r.p.m. The blower speed is therefore a little over 10,000 r.p.m. and a boost pressure of 16 lb./sq. in. or 2.07 ata. is provided. These British designed and built blowers are unique in racing practice in that they have four lobe rotors-an arrangement which produces a greater frequency on the delivery side of the blower and therefore a smoother outflow at the expense of some reduction in effective working capacity for a given size of casing.

The casing of the Wade blower is also remarkable for the use of a helical port, this also giving a more even delivery characteristic.

A Scintilla magneto is mounted vertically and placed adjacent to the supercharger, current being supplied to sparking plugs situate in the crown of the hemispherical combustion chambers ; each plug is deeply recessed into a light alloy spine superimposed on the cylinder head with which the valve cover mates, and both camshafts are therefore enclosed within one cover.

The camshafts themselves are mounted quite close to the centre line of the cylinder head, the 90-degree inclined valves being worked through rockers. Two valves per cylinder are used, the inlet valves being very much larger in diameter than the exhaust, and although no h.p. figures in supercharged form for this engine have been released

the fact that 100 h.p. has been claimed in the unblown state makes a figure of *circa* 180 h.p. a reasonable one for the blown version.

It is perhaps worth noting that with this engine, as with other types in which high crankshaft speed is combined with plain bearings, the latter are of the Vandervell thin-wall type. The crankshaft of the engine is, it should be noted, heavily counter-weighted.

Gearbox

The normal gearbox mounted in unit with the engine provides four forward speeds, but an alternative box giving a fifth overdrive ratio can be fitted.

Rear Axle

A live bevel-drive rear axle is used.

Rear Suspension

The position of the rear axle is controlled by link motion which is attached to torsion bars running parallel with the transmission line.

Front Suspension

The normal Type 1100 Fiat front suspension is used, this having a lower wish-bone surmounted by a single upper arm which connects through a rocker to an enclosed coil spring, the damper being embodied within the working mechanism.

Steering

The Fiat 1100 type of steering gear has two-piece track-rod placed ahead of the front wheel centres.

Frame

The Simca Gordini has a round tubular frame of thin-wall section made from high tensile steel.

Brakes

Hydraulic.

Body and General Features

As may be realised from the dimensions set out below, the car is remarkable for its small overall size. The driver sits immediately above the propeller shaft and ahead of a normal rear-mounted tank. Every endeavour has been made on this car to keep width, height and correspondingly low frontal area down to the lowest possible figure. The weight of the vehicle has been estimated at only 8 cwt. and if this estimate is correct the car may have the high power : weight figure of 310 h.p./ton with which to offset the somewhat low figure of 18 h.p./sq. ft. of frontal area. From these figures it is understandable that the car has been most successful on circuits which do not permit very high maximum speeds.

Dimensions

Wheelbase 7 ft. 4½ in. ; Track 3 ft. 8¼ in.

4.5-LITRE LAGO TALBOT

No car running in Formula I has had so old an ancestry as the " Lago " Talbot, or simply Talbot as it is known in Europe. Of the two lines in the pedigree, one runs back to the Clement-Bayard, the English design rights for which were purchased by a syndicate headed by the Earl of Shrewsbury and Talbot. This make was sold in England as the Clement Talbot car up to the outbreak of the 1914-8 war. The other line, represented in concrete form to-day by the site of the Paris works, goes back to the Darracq Company, and the two were merged in the Sunbeam-Talbot-Darracq combine of 1920. In the ensuing years the products of the French branch became known as Talbot-Darracqs and when the combine was dissolved in 1934 the British rights in the name of Sunbeam and Talbot passed into the hands of the Rootes Group, whilst Mr. Tony Lago secured the French factory and the rights in the name and trade mark of Talbot and Darracq.

The 1926-7 1½-litre straight-eight Talbot cars had been designed and constructed in this factory and the concern re-established its thirty-year-old associations with Grand Prix racing by entering single-seater models with 4-litre engines in the 1938-9 French Grand Prix and a number of other events. The 4½-litre model about to be described made its first appearance in 1948 and won a number of Grandes Epreuves in the subsequent two years.

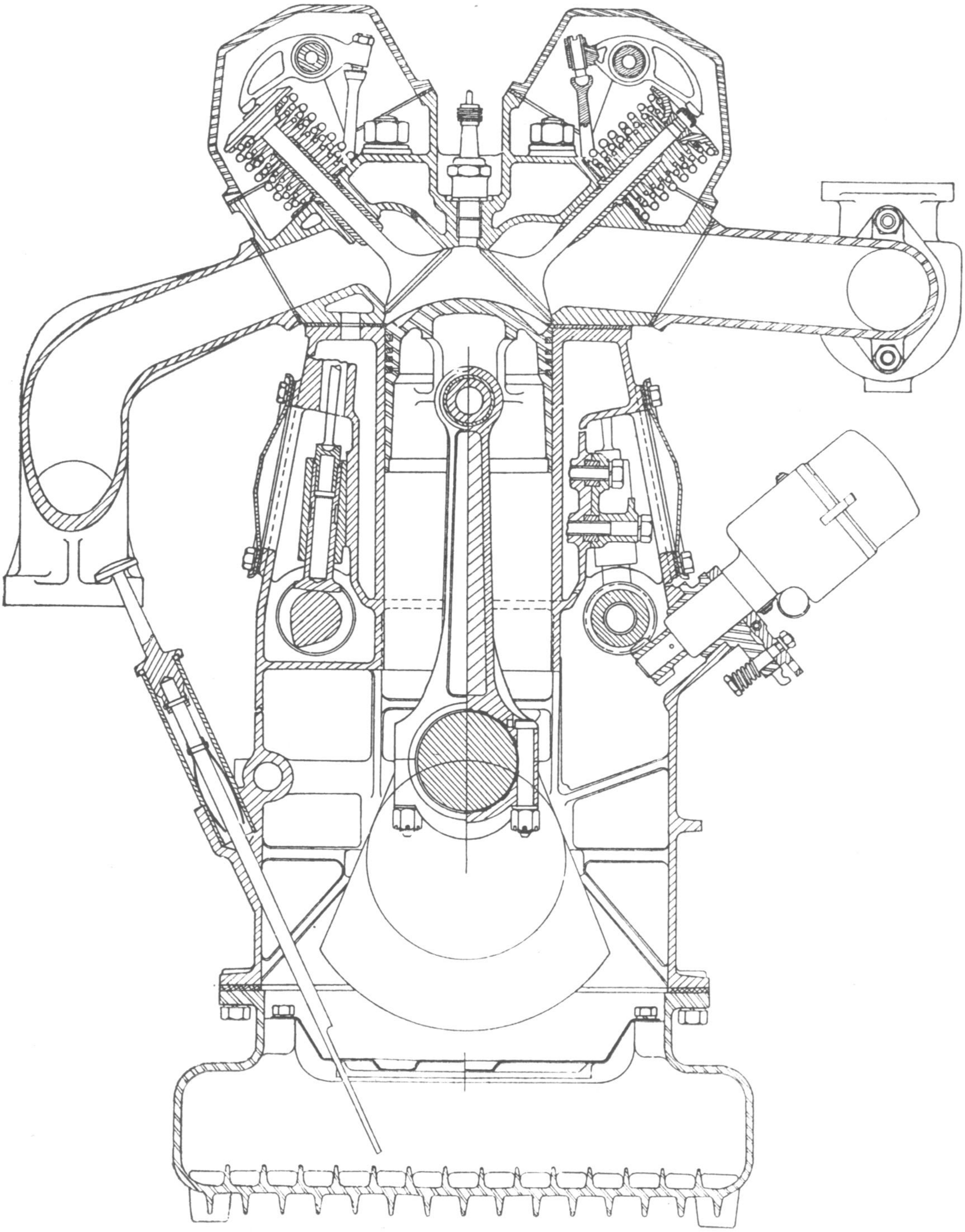
The 4½-litre Talbot Grand Prix racing car is very closely allied indeed to the standard production model known as the " Grand Sport " and even more closely to the two-seater type which has been prominent in the Le Mans twenty-four-hour and other sports-car races.

Engine

A single casting is used for the six-cylinder bores and the upper half of the crankcase and the hardened seven-bearing crankshaft runs in plain bearings.

The main casting extends well below the centre line of the shaft, with internal webs into which the bottom half of the main-bearing caps are recessed. At the top of the block there is a double wall between the water jackets which surround the bores and the outer face of the block. Tappets and push-rods moved by a pair of camshafts situate each side of the cylinders occupy this space and the push-rods extend through the cylinder head to engage with rockers operating two inclined valves per cylinder in the detachable light alloy head. These valves are inclined at an included angle of 90 degrees and a deeply masked sparking plug is placed between them. Cooling around the exhaust valve seat is improved by the complete inhibition of water flow between the block and the head on the inlet side and this forces all the discharge water through holes drilled immediately below the exhaust ports.

Three downdraught Zenith carburetters supply mixture to pairs of cylinders and receive air at ambient temperature from the long collector pipe which is housed in a scoop formed in the top of the bonnet. Fuel is supplied by two A.C. Mechanical fuel pumps mounted on the side of the crankcase and driven from the inlet camshaft. The magneto is driven from the front timing gears and on some 1950-1 models two sparking plugs per cylinder are fitted. A detail feature worthy of comment in an otherwise wholly straightforward layout is the elaborate system of oil cooling used on these cars. The scavenge pump feeds the oil back into a tank mounted beneath the



From 1948 onwards 4½-litre U/S Talbot cars have been fitted with six-cylinder engines having a detachable head fitted with two inclined valves per cylinder. These valves have been operated by double cam-shafts placed in the crankcase as shown in this cross-section. (Scale 1 : 4.)

scuttle and in the course of circulation oil has to pass through a large number of small diameter tubes which project through the scuttle.

Gearbox and Transmission

A four-speed Wilson pre-selector gearbox built upon the same principles as the unit employed by E.R.A. (*q.v.*) is bolted to the engine and immediately behind it is a housing containing spur gears which markedly offsets the propeller-shaft line to the right-hand side of the car.

Rear Axle

A live rear axle is employed, a deeply ribbed housing being split on the centre line of the casting.

Rear Suspension

Semi-elliptic springs support the car and take the torque on the Hotchkiss system, damping being provided by friction type shock absorbers supplementing direct-acting telescopic types which are inclined inwards at an angle of about 30 degrees.

Front Suspension

A transverse leaf spring forms the lower link of a wishbone system, the upper arms of which are formed of plates which have a shorter effective length than the appropriate half of the leaf spring. Friction type dampers are also employed at the front of the car.

Steering Gear

A worm and nut steering box is employed.

Frame

A box-section frame is used, the sides being pierced to save the weight and the section diminished in depth behind the rear spring hangers, at which point there is a down-sweep to pass the side-members beneath the rear axle.

Brakes

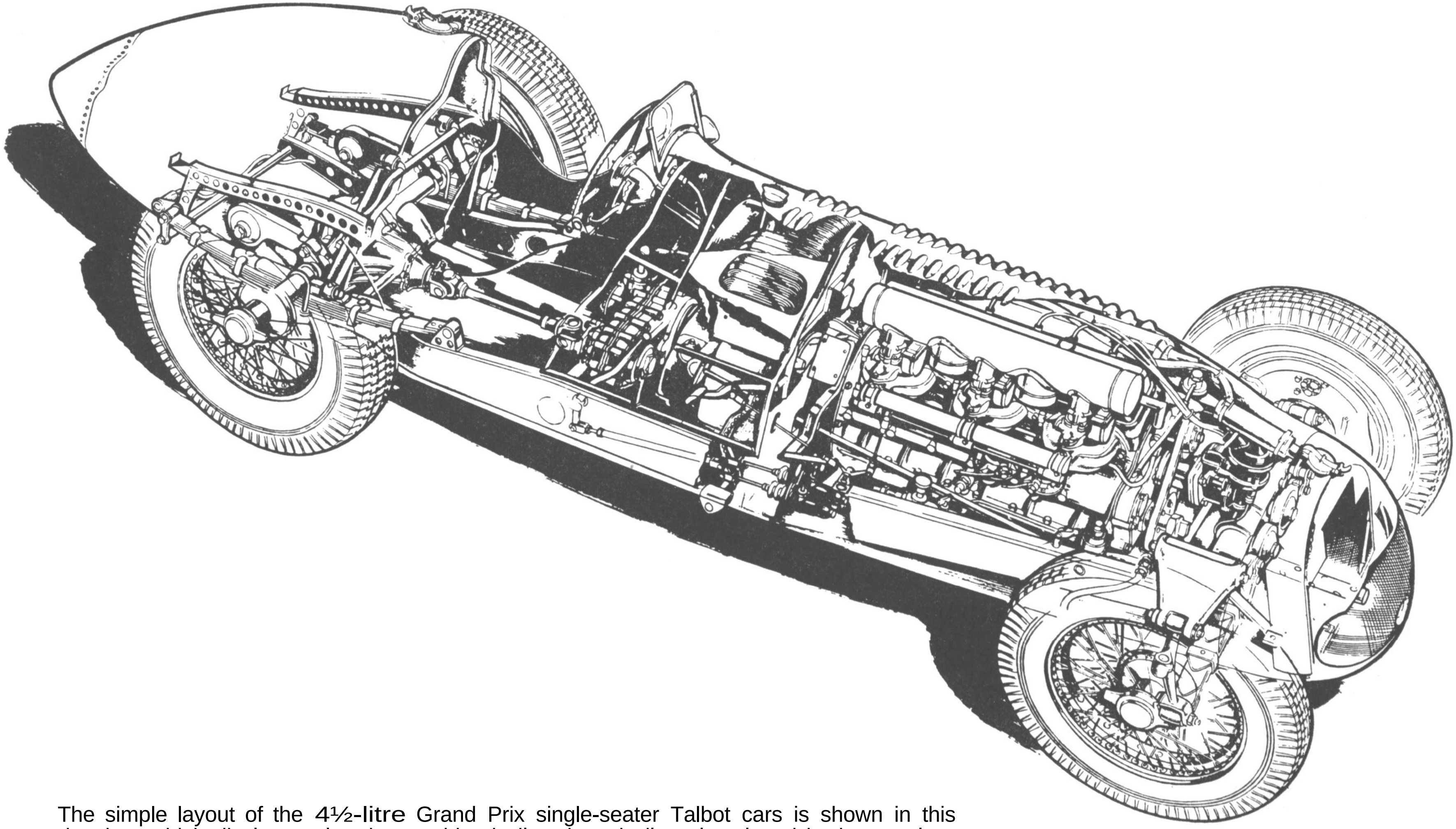
In the 1948-9 models cable-operated Bendix brakes were used, but the later models employ Lockheed brakes with two leading shoes, the fore and aft pairs being operated by individual master cylinder connected by a whiffle tree.

Body and General Features

The offsetting of the propeller shaft makes it possible to place the driving seat much lower than would have been the case with an orthodox propeller shaft and live axle. Despite the handicap of the longest stroke in Formula I racing with a corresponding tall engine, the whole car has been kept reasonably compact. Fuel is housed in the single tank behind the driver's seat and the performance of the cars in racing has been materially aided by their good fuel consumption, which has made it possible for them to cover the regulation distance of 500 kms. for a Grande Epreuve with only one stop for fuel.

Dimensions

Wheelbase 8 ft. 2½ in. ; front track 4 ft. 6 in. ; rear track 4 ft. 3½ in.



The simple layout of the 4½-litre Grand Prix single-seater Talbot cars is shown in this drawing, which discloses also the combined oil tank and oil cooler placed in the scuttle and the marked offsetting of the propeller shaft which enables the driver's seat to be placed below the level of the propeller shaft.

STATISTICS FOR RACING CARS, 1947-51

	1947 *Alfa Romeo Type 158*	1948 *Alfa Romeo Type 158*	1951 *Alfa Romeo Type 158*	1953 *B.R.M.*	*Cisitalia**	*E.R.A.*	*1.5-litre Ferrari*	*1.5-litre Ferrari two-stage*	1951 *4.5-litre Ferrari*	*Maserati 4 CLT*	*Lago Talbot*
Cylinders	8	8	8	16	12	6	12	12	12	4	6
Bore M/M	58	58	58	49.53	55	57.5	55	55	80	78	93
Stroke M/M	70	70	70	48.26	50.5	95.2	52.5	52.5	74.5	78	110
S/B Ratio	1.2	1.2	1.2	0.975	0.92	1.66	0.95	0.95	0.93	1	1.13
Engine capacity CM^3	1,488	1,488	1,488	1,488	1,440	1,488	1,498	1,498		1,498	4,485
B.H.P.	254	310	380	525	450	175	225	300	380	260	250
R.P.M.	7,500	7,500	9,000	10,500	10,500	7,000	7,500	7,500	7,500	7,500	5,000
B.H.P. per litre	171	206	253	350	300	117	150	200	84.5	173	60.2
B.M.E.P. lb./sq. in.	294	358	366	434	370	225	260	346	147	300	145
Piston speed f.p.m.	3,450	3,450	4,170	3,340	3,350	4,320	2,600	2,600	3,660	3,850	3,780
Piston area sq. in.	32.8	32.8	32.8	47.8	44.2	24.1	42.2	42.2	93.6	29.6	63.2
H.P. per sq. in. piston area	7.74	9.45	11.7	10.98	10.2	7.25	5.35	7.23	4.06	8	3.98
Piston area sq. in. per litre	21.9	21.9	21.9	31.8	29.5	16	28	28	20.8	19.7	14
Induction system	2.2 ata	2.7 ata	3 ata	5.7 ata	2.7 ata	2 ata	2.6 ata	2.6 ata	1 ata	2.6 ata	1 ata
Frontal area sq. ft.	10	10	10	10	10.5	13.5	9.8	9.8	10.75	11	12.5
H.P. per sq. ft. ..	27.5	31	36	52	43	13	23	30.5	32.2	23.6	20
Weight cwt. unladen	15.8	16.3	16.5	16	14.7	14.5	13.5	14.5	16	15	18
Weight with crew and fuel (cwt.)	19.5	20	21.5	20	20	18	17.25	18.25	19.75	18.5	22
Engine litres per laden ton	1.54	1.5	1.4	1.50	1.33	1.67	1.74	1.64	4.56	1.64	4.07
Engine B.H.P. per laden ton	260	310	354	525	450	195	260	328	386	280	227
Maximum road speed ; m.p.h.	165	175	190**	195**	190**	125	160	175	180**	160	155

* All Cisitalia figures are hypothetical. ** Determined by final gear ratio more than by b.h.p./sq. ft.

EXAMPLE No. EIGHTEEN

The Ferrari 4½-litre

ONE of the first tasks to which Aurelio Lampredi gave his attention in the midsummer of 1949 was the development of a new series of unsupercharged engines. He planned to fit these into the long chassis Formula II cars with de Dion rear axle for which he was also responsible, and he commenced work on the new engines in September, 1949.

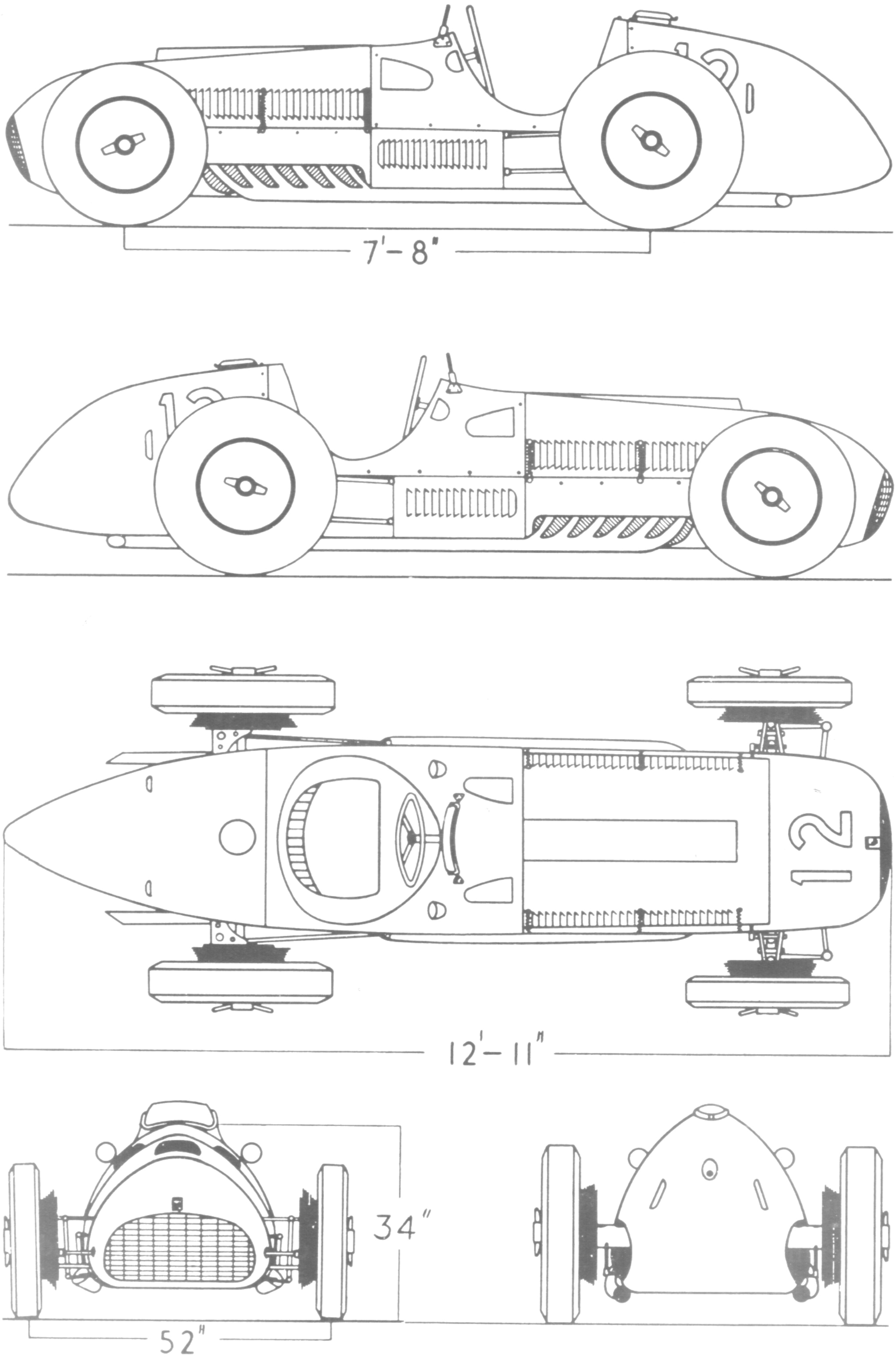
Full use was made of the knowledge and experience gained on the Colombo-designed single camshaft V12 engines of 1½ litres and 2 litres capacity which had a bore and stroke (in the 2-litre case) of 60 x 58.8 mm. The new series of engines were built in the first instance with a bore and stroke of 72 x 68, giving a swept volume of 3.3 litres, the enlargement of the bore being facilitated by a change in the cylinder liner location whereby the large diameter flange used for bolting together the liner and head on the supercharged models was eliminated, as was the simple face joint between the head and the liner characteristics of the earlier unblown types.

The 3.3-litre car made its racing debut in the Belgian Grand Prix of June 18th 1950, in which it was driven by Ascari, who was in practice not only twelve seconds slower than the fastest Alfa Romeo Type 158, but two seconds slower than the fastest 4½-litre Talbot driven by Sommer. In July the cylinder bore was raised to 80 mm. giving a swept volume of 4.1 litres, and the car appeared in this form for the Grand Prix des Nations held at Geneva on July 30th. In practice it now proved two seconds a lap slower than the fastest Alfa Romeo and four seconds faster than Sommer on the Talbot. For the Italian Grand Prix of September 3rd, and the Penya Rhin Grand Prix of October 29th, two cars were built with engines having the 80 mm. bore with the stroke increased to 74.5 mm., giving a swept volume of 4,494 c.c. or within 6 c.c. of the maximum permissible under Formula I.

In 1951 all the cars raced used the 4½-litre engines and their successes and relative lap speeds have already been recorded.

As already mentioned, although a new hand was engaged in the design of these cars, the general layout was basically similar to the smaller engines, a feature of interest common to the whole range being the use of a larger bore than stroke, with the consequence that the engine has, with one exception, the largest piston area of any racing car engine built since 1908.

The crankcase is split on the centre line of the crankshaft and provides a four-point mounting in the frame through the medium of rubber blocks. This light alloy casting also forms the water jackets for the cylinder liners, but some trouble having been experienced with the joint used on the detachable heads in the 1½-litre model, on the bigger engine a thread is machined in the combustion space into which the cylinder liner is screwed. Each head, with six pendant liners, can therefore be bolted to the block with the need for only one joint at the base of the liner, and that is required only to contain water, there being no gas joint in the design.



The 1951 Formula I twelve-cylinder Ferrari car to scale of I : 30.

There are additional advantages. A heat barrier between the head and bore is eliminated and, as already mentioned, the diameter of the cylinder bore (and of course of the combustion space) can be enlarged without increasing the distance between the cylinder axes. Each cylinder head is a single light alloy casting with inserted valve seats and two valves per cylinder, inclined at an included angle of 60 degrees, are used, the inlet being 1.625 in. diameter and the exhaust 1.465 in. diameter.

These proportions give an inlet valve area of 24.8 sq. in., which is 26.5 per cent of the piston area, and is equivalent to a flow value of some 15.3 h.p./sq. in. of valve area, a figure which is interesting to compare with the 9.7 h.p./sq. in. of the unblown 1922 3-litre Vauxhall, and which is even superior to the 15.1 h.p./sq. in. of the 1949 supercharged Ferraris which had a manifold pressure of 1.6 ata.

Each valve is closed by twin hairpin-type springs having ten effective coils of 1.26 in. diameter with a wire thickness of 0.157 in., and these must impose somewhat heavy loading on the rockers which are used in conjunction with the single overhead camshaft provided for each bank of cylinders.

The camshaft drive is by chain from the front end of the crankshaft, the latter running in seven Vandervell three-layer bearings which are indium plated and of 2.36 in. diameter. This type of plain bearing was first used on the smaller engines after exhaustive bench and road tests had shown that they not only had equal reliability and greater length of life but also produced an observable increase in mechanical efficiency. A similar type of bearing is used for the 1.73 in. diameter big ends, and attention should perhaps be drawn to the fact that the crank pins are only 55 per cent the diameter of the cylinder bore and the bearing area must be considered as rather on the small side taking into account the size of the pistons, the crank r.p.m. and the piston speed.

The light alloy pistons are steeply domed and provide choices of compression ratio lying between 11 and 14.5 : 1 and they are attached to steel H-section connecting rods which lie side by side on the crank pins with the cylinder axes at the orthodox included angle of 60 degrees, the firing order being 1, 7, 5, 11, 3, 9, 6, 12, 2, 8, 4, and 10, ignition on the earlier models of the type being provided by two Marelli magnetos mounted vertically at the back of the block and driven from the back of the camshafts at the camshaft speed. On the prototype a single sparking plug was used with provision for 40 degrees advance, and the maximum engine power was approximately 330 h.p. at 6,500 r.p.m., equal to 3,160 ft./min. During 1951 the works cars appeared with two sparking plugs per cylinder, and in this form 380 h.p. was given at 7,500 r.p.m., which is the equivalent of 147 lb. sq. in. b.m.e.p. at 3,660 ft./min.

Three downdraught Weber carburetters receive air from an external scoop formed in the bonnet top and feed fuel into a water-heated manifold. The carburetters are of the double-choke type, so each jet assembly, in effect, feeds two ports.

An alcohol-benzol blend fuel is fed into the float chambers by twin Frimac pumps. One of these is driven from the front of the right-hand camshaft and, as it is fed under pressure by a larger pump unit, it is mounted on the right-hand frame member below the driver’s seat and driven by belt from the propeller shaft. This first-stage pump in turn is fed under gravity from the fuel tank which is placed at the back of the car.

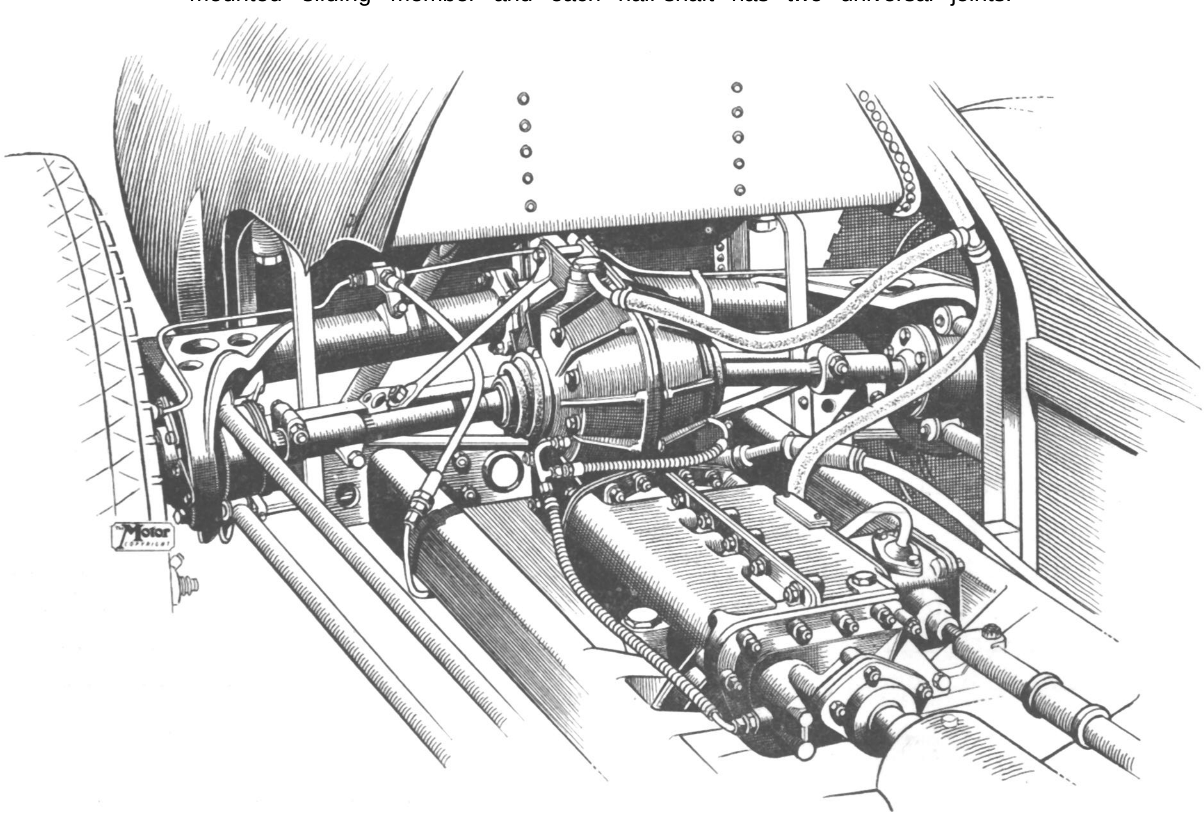
Lubrication is by wet sump with an external oil radiator. This is a very unusual arrangement for a racing engine, there being only one oil pump, which is a gear type

transversely mounted at the nose of the crankcase. Delivery from the pump is partially through the oil radiator with a thermostat preventing delivery to the radiator core until a certain oil temperature is reached, and a spring-loaded relief valve controlling exit therefrom so that the oil cooling system is under very light pressure. Oil is delivered to the main bearings at 70 lb. sq. in. through a gallery pipe extending the whole length of the engine, from which there are take-offs to each of the seven main bearings with normal cross drillings into the crank pins. The ribbed sump contains two gallons of oil.

A metal multi-plate clutch is bolted on to the end of the crankshaft and the four-speed transmission unit is bolted together into one aggregate and mounted at the tail of the car. By using a pair of spur wheels for the final drive it is possible to have the centre line of the propeller shaft of the bevel wheels substantially below that of the two exposed half-shafts, each of which have two universal joints. These are of needle type and resemble closely in design the American Mechanics joint. Both the spur box and gearbox proper are split lengthwise on their centre line and a very wide range of final and indirect gear ratios can be provided. A typical set gives an overall engine : road wheel relationship of 3.9, 4.55, 5.6, and 9.2 : 1 and with the normally used 7.50 by 17 rear tyres there are resultant road speeds at 7,500 r.p.m. of 173, 148, 120 and 73 m.p.h. Very ample provision is made both for lubricating the train of gears and for adequate breathing from the gear cases without loss of oil therefrom.

The rear wheels are maintained parallel with each other and vertical with the road by a de Dion tube which is made in three parts, but does not require any provision

The final drive on the Ferrari is by means of spur gears, the right-angle drive being placed beneath the centre line of the half-shafts so that the gearbox and propeller shaft can conveniently be placed below the driver's seat. As shown below, the de Dion axle tube is located sideways by a centrally-mounted sliding member and each half-shaft has two universal joints.



for oscillating movement of one side against the other, such as was provided on the pre-war German racing cars. This follows from the fact that the radius arms which drive the car and contain engine torque and brake reaction are formed in pairs and lie parallel one above the other in the same plane as the wheels.

The arms are 21.2 in. long between their pivots and the duty of locating the de Dion tube sideways is performed by a pad on the leading edge of the de Dion tube. This runs in a slot attached to the back of the transmission housing coupled with a roller on the trailing edge of the de Dion tube which engages with a slot fixed to a tubular arch extending between the extreme rear ends of the frame side tubes. This arrangement obviously assists the radius arms in maintaining the rear wheels square with the chassis, in addition to providing the normal resistance to side thrust.

The Ferrari de Dion tube is typical of the efforts which are made to keep the weight of the car down, for it has a wall thickness of only 2 mm. and a diameter of only 2.36 in. The suspension is, somewhat surprisingly, effected by a single transverse leaf.

The same arrangement is used at the front end of the car, the leaf connecting to the lower and longer link of a conventional wishbone layout.

Both the front and rear springs have six leaves, each 1.77 in. wide and 35.4 in. long, and the mounting of these springs on the chassis is such as to provide the maximum effective length. Damping is provided fore and aft by quite small vane-type hydraulic shock absorbers, but due perhaps to the relative stiffness of the suspension these are found to give excellent results over a complete racing season.

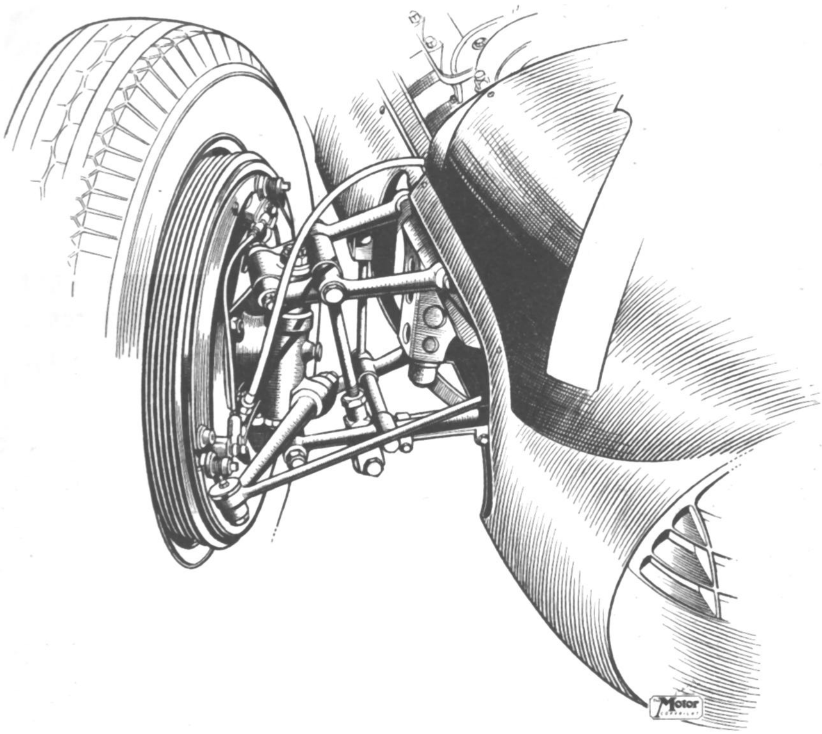
A conventional worm and wheel steering box is used, giving 1-7/8 turns from lock to lock, the steering box itself being located on the offside of the front cross-member and being joined to the central steering wheel by a long articulated steering column.

A conventional three-piece track-rod is used, a heavy drop arm pivoting around the left-hand side of the cross-member with a fixed track-rod connecting it to the steering arm proper. Short swinging arms connect to the steering pivots, the king-pin bearing being placed between the wishbones.

The frame has two parallel tubes as side-members, these being of rectangular section. The dimensions vary somewhat, but, approximately, the tubes are 4.7 in. deep and 2.25 in. wide. A round tube of 3 in. diameter provides cross-bracing between the clutch housing and the gearbox and torsional stiffness is further provided by a built-up plate at the front which also supports the suspension elements and steering gear and a further pierced built-up cross-piece lying immediately behind the two exposed half-shafts.

The outstanding feature of the hydraulic brakes of the two leading shoe type is the very marked projection of the drums from the wheel rims so that maximum air circulation can be provided around the periphery of the drum.

As with the Formula II racing cars, the two leading shoes have a central guiding member so that any servo shoe effect is almost eliminated. The front and rear pairs of brakes are worked from separate master cylinders and a point of particular interest lies in the forced ventilation provided for the brake drums. Radial air scoops are cast into the face of the drum (which is of light alloy with an inserted steel liner) and it has been established that the air flow provided by this means is a very effective way of reducing temperature both of the drum itself and of the shoes and brake linings.

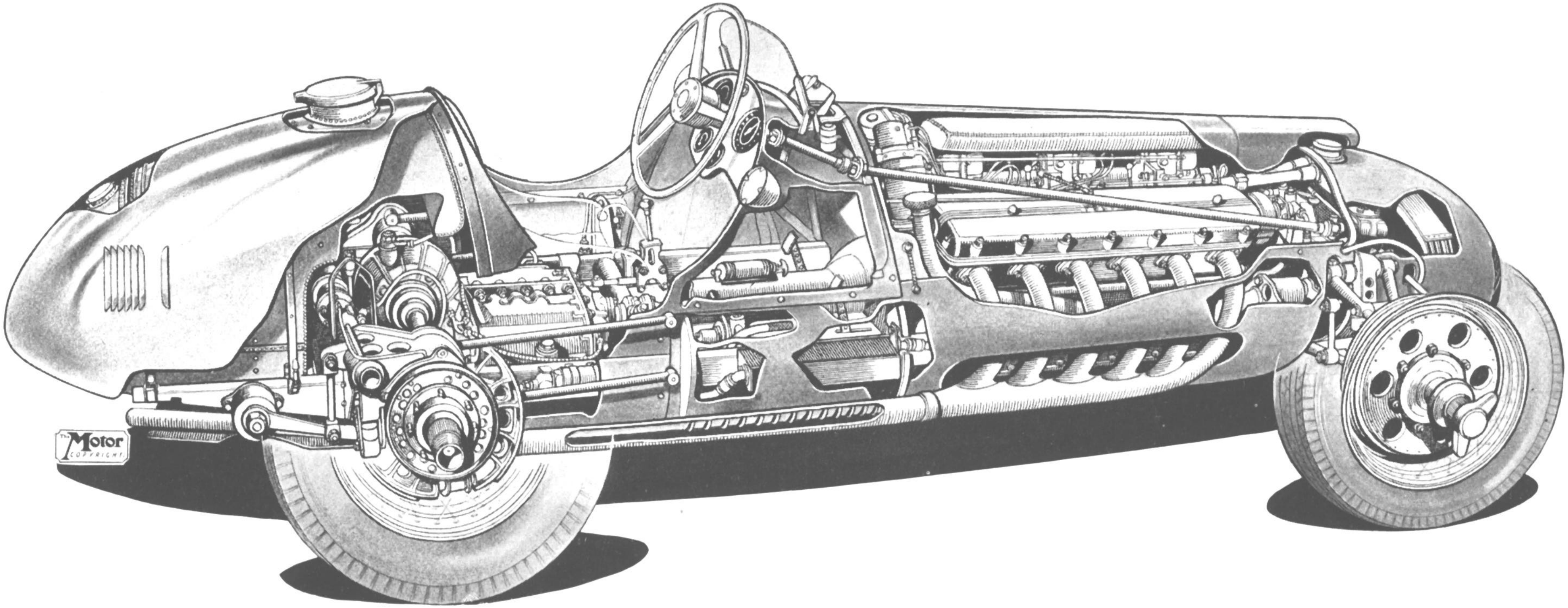


The front suspension of the Ferrari is by two unequal-length wishbones, a single transverse leaf spring being connected to the top arm by a link (as shown here) on earlier models and directly to the lower arm on the latest types. The drawing shows the considerable offset of brake drum and king-pin in relation to the tyre centre and the forward mounting of the three-piece trackrod system.

The 4½-litre Ferrari is a very handsome-looking car, the front end of which has a very over-shot appearance, the tail being as short as possible, consistent with the provision of 45 gallons of fuel. The very latest type which ran in the Grands Prix of Italy and Spain, in 1951, had an even more impressive aspect, obtained by noticeably raising the height of the scuttle and fitting a high backrest for the driver’s head on the top of the tank.

For the Indianapolis race of 1952 and for the relatively few Formula I and *formule libre* races for which the works entered a car in 1952 and 1953, modifications were made to the engine, the frame and the general appearance. By detailed changes to the air intake and carburation layout the maximum power was raised to 430 b.h.p. and the bonnet line was lowered with the provision of a mid-bonnet air scoop intended to give some ram effect to the ingoing charge.

The tail of the car has also considerably altered so that the appearance of the 1952 and 1953 model, as shown in one of the plates, is considerably at variance with the 1951 Grand Prix model which is the subject of the cut-away drawing. A major mechanical change on the Indianapolis type car was a strengthening of the frame by welding a triangulated system of small diameter tubes on top of the normal side-members. This is also illustrated on a plate.



PLATF IV

EXAMPLE No. EIGHTEEN

THE 4½-litre FERRARI

The 4½-litre Ferrari depicted here is a 1951 type modified by fitting Girling brakes. The drawing shows how the V.12 engine is placed far back in the tubular frame with the four-speed gearbox mounted beneath the driver's seat. The de Dion axle tube is located by two parallel radius arms on each side, which makes possible a non-articulated de Dion tube.

DETAILS OF CAR

MAKE.-Ferrari
TYPE.-Formula I Grand Prix car
YEAR OF CONSTRUCTION.-1950-53
YEARS RACED.-1950-53
DESIGNER.-Aurelio Lampredi
WHEELBASE. -7 ft. 8 in.
FRONT TRACK.- 4 ft. 3½ in.
REAR TRACK.- 4 ft. 3 in.
FRONTAL AREA.-10.75 sq. ft. with driver
UNLADEN WEIGHT.- 16 cwt.
ALL-UP STARTING LINE WEIGHT.-20.75 Cwt.
MAXIMUM SPEED.-175 m.p.h.
SPEED ON INDIRECT GEARS.-148 m.p.h. on Third ; 120 m.p.h. on Second ; 73 m.p.h. on First
H.P. PER SQ. FT.-32.3
H.P. PER TON UNLADEN.-485
H.P. PER TON ALL-up.-366
BORE.-80 mm.
STROKE.-74.5 mm.
STROKE : BORE RATIO.- 0.93 : 1
PISTON AREA.-93.6 sq. in.
H.P.-380 at 7,500 r.p.m.
H.P. PER SQ. IN. OF PISTON AREA.-4.06
B.M.E.P.-147 lb./sq. in.
PISTON SPEED.-3,660 ft./min.
CYLINDER HEAD.-Light alloy, cast with block
VALVES No.-Two per cylinder
VALVES ANGLE.-60 degrees
VALVE AREA.-Inlet : 24.8 sq. in. ; Exhaust : 20.2 sq. in.
CYLINDER BLOCK.-Wet cylinder liners screwed into cylinder head inserted into water jackets formed in crankcase
FUEL.-Petrol/Benzol/Alcohol mixture
CARBURETTERS.-Three Weber
SUPERCHARGER.-Nil
MANIFOLD PRESSURE.- One Ata.
IGNITION.-Two Marelli magnetos
PLUGS No.-24
PLUGS LOCATION.- At side of combustion chamber
CRANKCASE.-Light alloy casting with light alloy sump added
CRANKSHAFT.-One-piece
MAIN BEARING No.-Seven
MAIN BEARING TYPE.-Vandervell three-layer thin-wall
BIG END TYPE.-Vandervell three-layer thin-wall
LUBRICATION.-Wet Sump
CAMSHAFT LOCATION.-One overhead camshaft per bank
VALVES OPERATED.-By rockers
CAMSHAFT DRIVE.-Roller chain
CAMSHAFT DRIVE LOCATION.-Front of engine
CLUTCH.-Single-plate
GEARBOX LOCATION.-In unit with rear axle drive
GEAR RATIOS.- 3.9 ; 4.55 ; 5.6 ; 9.2 : 1 ; other ratios available
TRANSMISSION.-By shaft running below hub centre to four-speed and bevel box with final drive by spur wheels to two exposed half-shafts each with two Hooke type universal joints
FRAME.-Rectangular tube
FRONT SUSPENSION.-unequal-length wishbones with transverse leaf spring
REAR SUSPENSION.-de Dion axle located sideways by two sliding members with drive and torque reactions contained by two parallel radius arms at each side of the car
SHOCK ABSORBERS.-Houdaille Vane type hydraulic
BRAKE SYSTEM.-Hydraulic
BRAKE DRUM DIAMETER.-14 in. internal
FRICTION LINING WIDTH.-2.24 in.
SQ. IN. OF DRUM PER LADEN TON.-376 sq. in.
WHEELS.-Rudge detachable
TYRES.- Pirelli 6.00 by 16 front ; 7.50 by 17 rear

FORMULA I RACING RECORD FERRARI 4½-LITRE

Date	*Event*	*Course*	*Average Speed m.p.h.*	*Lap Speed m.p.h.*
16/8/51	Pescara	Pescara	85.32	88.86
29/10/50	Penya Rhin	Pedralbes	93.8	98.2 (P)
17/6/51	Belgian Grand Prix	Spa	112.20 (2nd)	117.5 (P)
7/51	European Grand Prix	Rheims	110.5 (2nd)	117.95 (P)
14/7/51	British Grand Prix	Silverstone	96.11	100.65 (P)
29/7/51	German Grand Prix	Nürburg Ring	83.76	85.69 (P)
27/5/51	Swiss Grand Prix	Berne	87.4 (3rd)	102.2 (P)
16/9/51	Italian Grand Prix	Monza	115.53	122.5 (P)
28/10/51	Spanish Grand Prix	Pedralbes	98.6 (2nd)	108.1

EXAMPLE No. NINETEEN

The Formula I B.R.M.

ALTHOUGH the B.R.M. entered but four Formula I races between 1947 and 1951 (1950 British Grand Prix and Penya Rhin, and 1951 British and Italian Grands Prix), although it left the starting line in only two of these events, and although it finished in only one of them, it can, nevertheless, claim to be the car with the highest theoretical performance within the framework of the Formula I regulation and, theory apart, in timed tests at Monza it reached a higher maximum speed on some parts of this circuit than the 1951 Alfa Romeo and raced on generally level terms with the 4.5-litre Ferrari in the minor races of 1952 and 1953.

In 1939 the triumvirate, Humphrey Cook, Raymond Mays and Peter Berthon, who had been responsible for the highly successful E.R.A. models of 1934-38, was broken up, but during the ensuing wartime years Mays and Berthon remained in close association and enjoyed a common aim. This was to put the British automobile industry " on the map " in the realm of Grand Prix racing in the immediate post-war years.

The Grand Prix Formula reigning in 1938 and 1939 had received somewhat meagre support, and before the outbreak of war the possibility of a 1½-litre limit for Grand Prix racing had been freely discussed. Mays and Berthon therefore took this as a starting point in making some general investigations during the war years and, acting upon theoretical considerations which will be considered in detail in another chapter, they concluded that the correct solution to the problems posed by a 1½-litre limit was to be found in a V.16 engine with a centrifugal blower, driving an offset and diagonal propeller shaft connected to a spur type gearbox and final drive set across the back of the frame.

By this means it would be possible to obtain a piston area of 48 sq. in. offering, at accepted standards, an output of up to 480 b.h.p. This could be coupled with a frontal area of 9½ sq. ft. giving 50 h.p./sq. ft. of frontal area-a figure superior not only to that achieved on any known or potential 1½-litre car, but also substantially in excess of the 39 h.p./sq. ft. on the 1939 3-litre Grand Prix cars.

A decision to embark upon the design and construction of a vehicle of this kind could be justified only on the basis of the long-term benefits which were likely to accrue, given a substantial support, both physical and financial, for the venture. An alternative would have been to lay down a type having a Vee-8 engine supercharged by a Roots or Vane type compressor with a unit gearbox driving to a rear axle of the live or swing axle type. Using known technique, such an engine could have given 300 h.p. with reliability early in its life, and could have been developed to a limit of about 380 b.h.p. and about 36 h.p./sq. ft. of frontal area. Its overall racing history could have been estimated as follows :

1946-mid-1947	Design and construction
Mid-1947-end 1947	Appearance of prototype
1948	Commence team racing
1949	Design at peak of efficiency and success

1950	Design obsolescent
1951-2	Obsolete

The time picture for a complicated engine capable of development up to 600 b.h.p. and mounted in a relatively intricate chassis could be reckoned thus :

1946-9	Design and construction
1949	Trials with prototype
1950	Commencement of team racing
1951-2	Design at peak of development

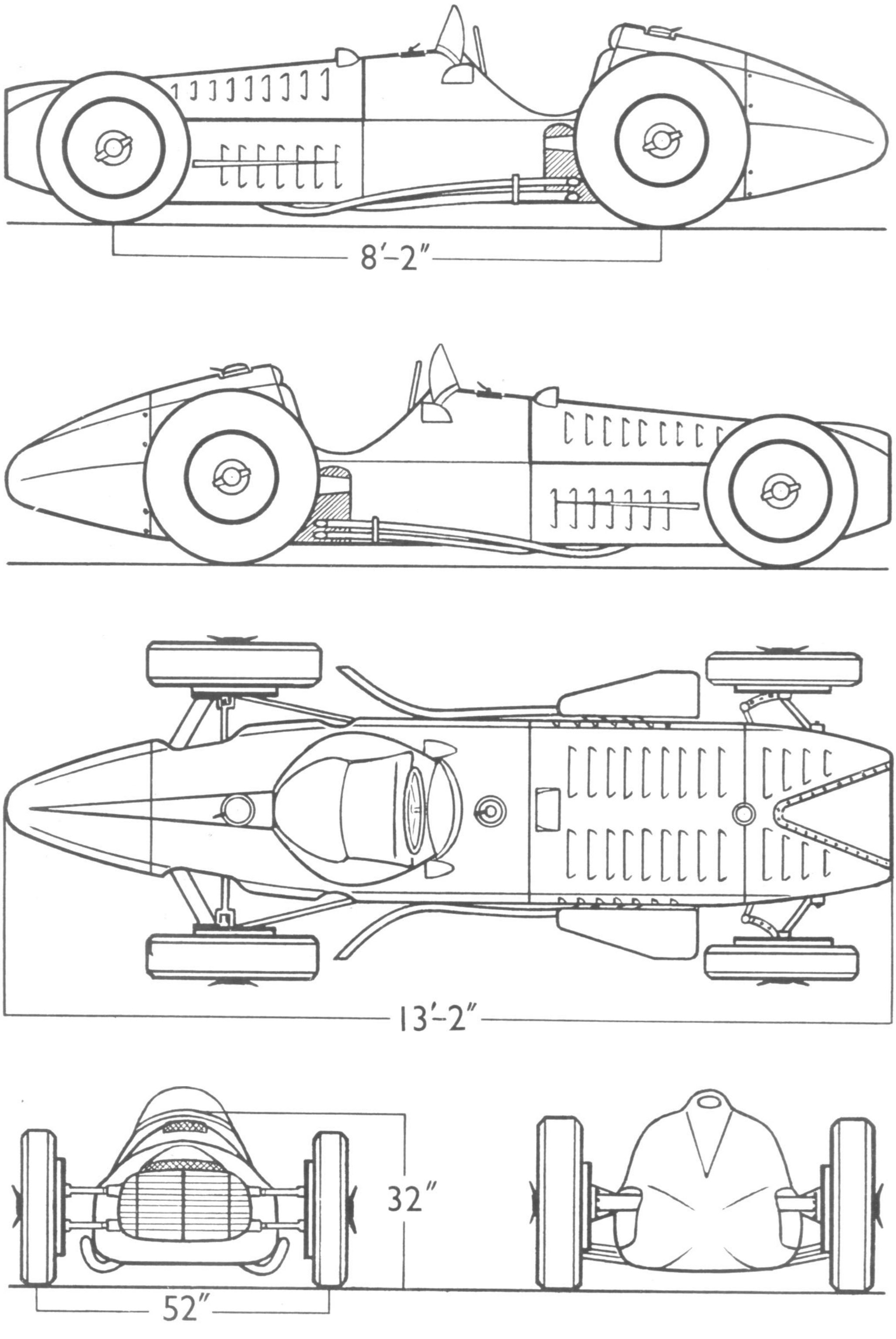
In both cases one might reasonably expect occasional victories in 1950, but with the more complex design this should have been followed by increasing technical dominance in Grand Prix racing right up to the end of 1952. This was an obviously more desirable state of affairs from the point of national prestige and propaganda than a steady succession of losses in these years, leading to the withdrawal of the team from international competition.

Unfortunately, although the B.R.M. directors made the correct strategic decision in deciding to build a car which could offer increasingly competitive performance, the design and production stage took much longer than was at first estimated. Moreover, owing in part to limits on the financial and physical support enjoyed, and in part to certain errors in the policy followed, the whole development programme was delayed by approximately two years, and the car reached its zenith when Formula I racing was superseded for the Grandes Epreuves by races for unsupercharged cars of lesser swept volume.

The power unit is noteworthy for the use of sixteen cylinders, each having a capacity of only 93 c.c., the bore and stroke each being less than 2 in. This means that the crank throw is less than 1 in. and the cylinder block and crankcase proper are quite overwhelmed, when viewing the engine, by the cylinder heads and valve gear, and the ingenious arrangement for auxiliary drives. This may best be appreciated by stating that the main casting is under 31 in. long, 13½ in. wide, and only 7 in. deep, whilst the base is some 10 in. deep, and the cylinder heads are about 10 in. wide.

The cylinders are arranged in four separate groups, two on each side of the crankshaft, and their axes are inclined at an included angle of 135 degrees. This arrangement gives even firing order, keeps down the overall height of the engine to a minimum and at the same time lifts the cylinder heads above the level of the frame tubes, which they might have fouled if a flat engine having horizontally opposed cylinders had been used. The top half of the crankcase is a one-piece light alloy casting which provides the water jackets for all the cylinders and the supports for the ten main bearings (eight of which are of the Vandervell thin-wall three-layer type) in which the two-piece, eight-throw, Nitralloy crankshaft runs.

Beneath this main casting is a deep magnesium alloy sump containing a sub-shaft, and it seems appropriate to commence a detailed analysis of the engine with a description of this unique feature. As can be seen from the sectional and perspective drawings, the clutch is attached to a shaft of which the centre line is 4 in. below the centre line of the crankshaft. This sub-shaft is 1.2 in. diameter and supported in three ball bearings. It not only drives the car but also, through the intermediary of two skew gears, the pressure and scavenge pumps for the lubricant and the water pumps.



The 1953 Formula 1 sixteen-cylinder B.R.M. to scale of 1 : 30.

In the rear section of the sump a transverse shaft driven by the skew gear extends to the left-hand side of the engine and is supported in two plain bearings. Keyed to it and mounted inside the sump is a pressure oil pump, and mounted externally to the crankcase is a centrifugal water pump. On the right-hand of the crankcase a separate transverse shaft is driven through a dog, and mounted upon it is a scavenge oil pump, both oil pumps being of the gear type of the same diameter (3¼in.) but the scavenge pump gear teeth being 0.75 in. wide, whereas the pressure pump is 0.45 in. In the forward section of the sump an exactly similar arrangement is found, but with drive and mounting in the opposite sense.

Mounted beneath this driving shaft is a second torsionally-resilient sub-shaft running forwards and engaging with a pre-set friction clutch which forms the first stage in a train of gears driving the supercharger. This shaft is driven from the main sub-shaft at twice the rotational speed thereof by two sets of spur gears.

This, in fact, brings the supercharger drive shaft back to crankshaft r.p.m., for the clutch shaft is itself driven at half engine speed from two gear wheels placed in the centre of the two-piece crankshaft. There are roller bearings on each side of these gear wheels, and each section of the crankshaft is further supported in four Vandervell main bearings, the journals being 2.3 in. diameter and the crank pins 1.5 in. Both sections are made from E.S.C. Nitralloy and are counter-balanced by inserts of G.E.C. heavy metal.

The main bearing caps are spigoted into the crankcase (which is a casting in RR 50 alloy), located by dowel pins and pulled up by long through bolts which emerge through the top face of the main casting. This casting is stiffened sideways by tie rods which pass transversely through the main bearing caps.

The detachable cylinder bores are spigoted into the crankcase with a bottom sealing joint and are made of cast-iron, with a double diameter flange on their top face which engages with a correspondingly shaped recess in the light alloy cylinder heads.

There are four separate heads, each containing four hemispheres with two unequally sized valves with an offset masked Lodge sparking plug. Each head also supports two camshafts which operate the valves through rocking fingers with hairpin valve springs; both valves are pulled down on to seat inserts and the smaller exhaust valve has a hollow stem with sodium assisting the heat transfer into the finned exhaust valve guide which is in direct contact with the circulating water.

The Y alloy pistons give a compression ratio of about 6 : 1, carry three compression rings and have a somewhat lowly positioned gudgeon pin which has a diameter of 15 mm., or approximately 30 per cent of the cylinder bore. The connecting rods are of nickel-chrome steel and although they are of conventional proportions they are only 4.125 in. long absolutely. There are two rods lying side by side on each crank pin, the offset between the cylinder axes being 16 mm., and as with the big ends the bearings are of the Vandervell three-layer type. With a length : diameter ratio of only 0.27 : 1 they are exceptionally narrow, but excellent results have been obtained throughout the whole life of the engine despite the use of abnormally high rotational speeds.

This is the more remarkable in that the high ratio between piston area and oil cooling area resulted in oil temperatures of up to 140 degrees C. being encountered in normal racing.

The pressure pump supplies 20 gallons of oil per minute at a pressure between 50 and 70 lb. per sq. in., the former figure being a minimum. Great emphasis is placed upon the supply of clean oil and a Tecalemit filter is embodied in the circulating system. An interesting feature of the latter is the adoption of the Rolls-Royce practice of end feed through the crankshaft to the big end bearings, the shaft being irrigated through circumferential grooves in the centre and two end bearings. The main bearings in this arrangement are supplied through separate delivery pipes, the oil escaping from them to be picked up by the scavenge pump.

S.A.E. 30 oil is used, B.P. Energol having been selected in 1952 and used thereafter.

This account of the constructional aspect of the engine may be closed with a reference to the camshaft drives which consist of a train of four spur wheels located on a carrier between the two cylinder blocks. Ignition is provided by Lucas coil and distributor, there being four of the latter, each driven from the nose of a camshaft and supplying current to four plugs. Each distributor has three contacts, one to open, and one to close the circuit, and a third which can be selected to provide a retarded spark when starting.

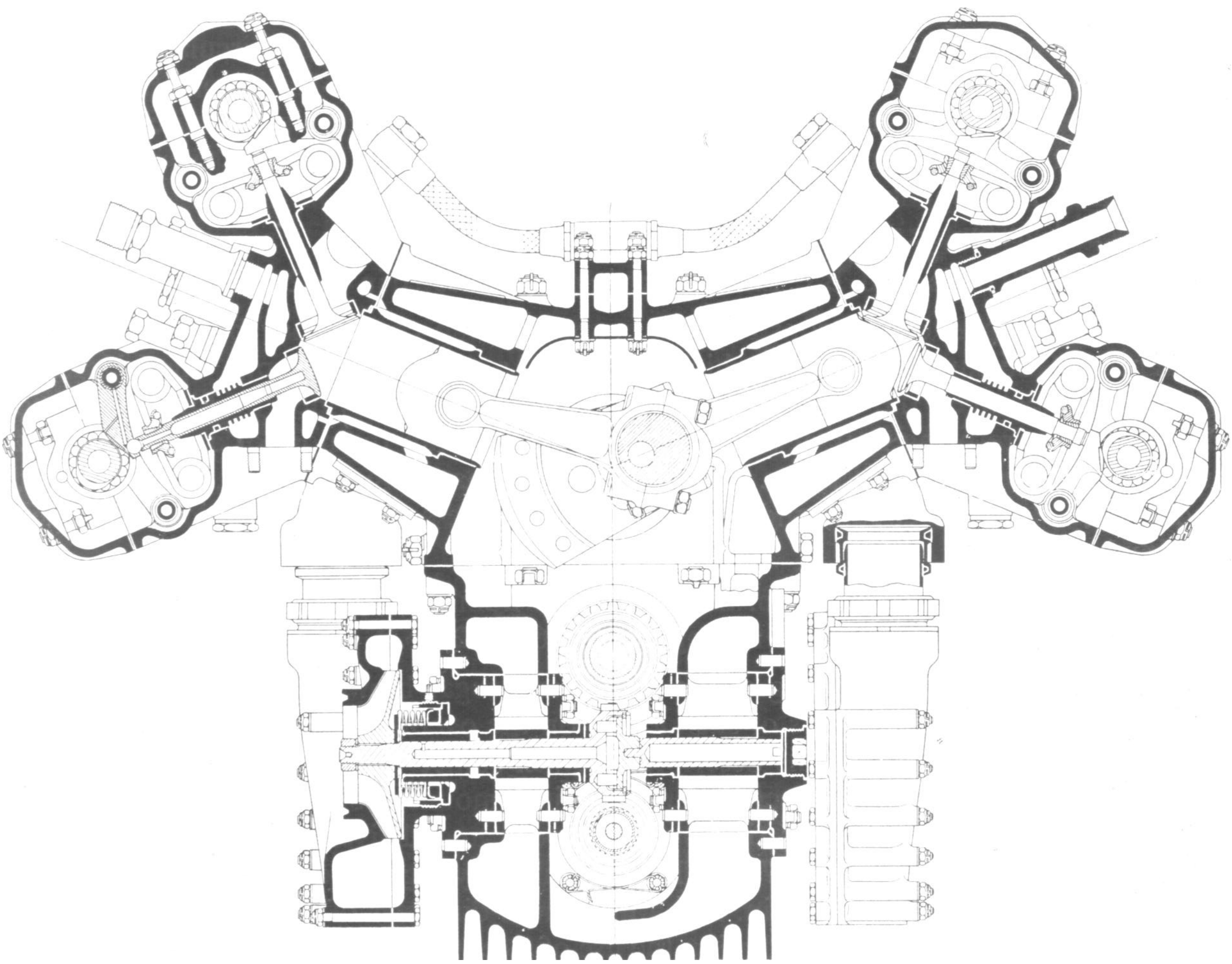
At maximum engine r.p.m. the formidable number of 85,000 sparks per minute has to be delivered, the firing order being : 1, 10, 6, 13, 2, 16, 5, 11, 8, 15, 3, 12, 7, 9, 4, 14.

The reasons for choosing a two-stage centrifugal blower and the effect of the inherent delivery characteristics of such a unit on the overall performance of the engine are discussed elsewhere. In this description it will suffice to record that the unit is of Rolls-Royce design and manufacture, and that it is mounted on the nose of the crankcase, being driven at over four times engine speed and delivering fuel/air mixture at approximately 70 lb./sq. in. or 5.7 ata. Despite this very high air delivery the component has an overall length of under 5 in. and a maximum diameter of 12 in. From the viewpoints of weight and ease of installation the use of a centrifugal blower cannot, therefore, be challenged and at the same time very high adiabatic efficiencies are recorded at peak speed and pressure-an important factor when it is realised that a 1 per cent variation in blower efficiency can affect net engine output by 5 per cent or more.

Although originally designed to use fuel injection, the car as raced has drawn mixture from two horizontal S.U. carburetters which are in turn supplied with fuel by a Pesco mechanical pump. Mixture is discharged into a single feed pipe running between the cylinder blocks, this having two offtakes on each side into cast manifolds supplying the four inlet ports per cylinder head.

Even on early trials, in 1949, the B.R.M. engine delivered over 400 h.p., representing an output of 8.6 h.p./sq. in. of piston area, and a b.m.e.p. of over 330 lb./sq. in. At this stage therefore it showed 26 per cent gain in b.h.p. per litre over rival six- or eight-cylinder engines, an achievement following a crankshaft speed of over 10,000 r.p.m. in place of *circa* 7,000 r.p.m., which was the limit for engines with larger diameter cylinders and longer piston travel. In the course of development over four years, supercharger speeds and pressures were steadily raised on the B.R.M. so that when operating on a full boost of 5.7 ata. the engine output came up to 412 b.h.p. at 9,000 r.p.m., to 525 b.h.p. at 10,500 r.p.m. and to 585 b.h.p. as an absolute maximum, this last figure determined by the limit on air flow of available carburetters.

Taking the 1953 figure as a basis of calculation, the engine was giving 11 b.h.p. per sq. in. at 3,300 ft./min. piston speed, with a b.m.e.p. of 434 lb./sq. in.



Many of the leading features of the B.R.M. engine are shown in this cross-section, including the hairpin-type valve springs, sodium-cooled exhaust valves, detachable cylinder heads and wet cylinder sleeves. The crankshaft drives the central intermediate shaft shown in the deep base chamber, the lower of the three shafts running forward to provide the supercharger drive. Two transverse shafts drive internally-mounted pressure scavenge and oil pumps and external water pumps. Scale 1 : 4.

Impressive as these figures are absolutely, they are lower than one might expect in relation to the very high supercharge pressure and the relatively small power absorbed by the blowers. The figure of 26.75 h.p./sq. in. of inlet valve area at 5.7 ata. certainly compares unfavourably with the 18 h.p./sq. in. at 2.45 ata. achieved on the 1939 Mercedes-Benz. It would appear, therefore, that the small size of the cylinders, although advantageous from a mechanical point of view, is a disadvantage from a volumetric standpoint owing to excessive interference with flow due to the interposition of valve stems, valve guides and so on.

The entire power unit is set in the frame with the axis of the crankshaft inclined downwards and sideways so that the propeller shaft passes to the left of the driver's seat, which can accordingly be placed in the centre of the car and barely 4 in. above ground level.

A multi-plate clutch is attached to the rear end of the sub-shaft, the plates being 7½ in. diameter with Ferodo lining attached to four driven plates not only by rivets but also by a Redux synthetic bond. By the use of bob weights centrifugal force augments the pedal pressure, the torque carried through the clutch being twice the engine torque, due to the fact that it is running at half crankshaft speed.

An open propeller shaft carries the drive to a centre bearing mounted on the cross-member of the chassis placed just ahead of the driving seat. To protect the driver the shaft is enclosed as it passes through the cockpit on the left-hand side of the seat to right-angled gears placed at the extreme left of the car.

The 1 : 1 bevel gears are mounted on the extreme left-hand side on a split light alloy casting measuring 20 in. long and 8½ in. wide, which supports in five bearings two transversely mounted shafts which give five forward speeds and also drive the exposed half-shafts through the medium of a pair of spur wheels and a Z.F. limited slip differential. The final spur wheel is enclosed in a detachable light alloy casting and the entire assembly (which is three-point mounted on the frame) gives support to two steel faces in which a bronze block slides to give axial support for the rear axle. With this transmission arrangement a very wide choice of ratios is available, typical gearing for the final stage giving 16.5 m.p.h. per 1,000 r.p.m. and 95, 115, 130, 165 and 190 m.p.h. on the various ratios. The unit scaled 162 lb. complete.

The whole of the transmission and rear-end layout of the car is obviously derived from pre-war Mercedes-Benz practice, the gearbox closely resembling the type shown on page 231 and in cross-section in Chapter XXII.

The de Dion rear axle and radius arms also resemble closely the layout described in detail in Volume I Example No. 16 and subsequently used by Mercedes-Benz on their 1938-9 3-litre Type W.163 models and their 1939 1½-litre Type W.165.

The separately machined hubs are mounted upon straight axle tubes which are in turn bolted on to a centre piece which permits one side of the axle to oscillate slightly in relation to the other, and which further provides a mounting for the central sliding bronze block. The axle beam is located in a fore and aft direction by a radius and torque arm on each side ; these are inclined slightly inwards, to pivot points mounted on the top part of the frame. Each wheel is driven by an exposed shaft having a de Dion pot-type joint on the inner end and a normal Hooke joint at the outer end, and with this layout it is unnecessary to use a splined shaft.

Two Lockheed air struts are placed between the de Dion tube and the frame, and these embody hydraulic damping arrangements so that both functions are discharged at a weight penalty of under 4 lb. per spring.

Lockheed air struts are also used at the front of the car, which has Porsche type trailing arms with the front wheels connected thereto by the usual ball joints.

Each arm is supported in a light alloy casting on needle roller bearings, the arms themselves being 8 in. between centres and splayed outwards at 50 degrees. In the first instance the Lockheed struts were moved by a short crank placed inboard of the mounting bracket and connected to the upper trailing arm. In order to increase the stroke of the strut it was later connected to the bottom arm at some distance from the front pivot thereof. These springs offer a variable rate, and cannot therefore be directly compared with the more othodox type but although mechanically, the limits of motion

on the front wheels permit a travel of 6 in. (and on the rear wheels of 7 in.) the springs were adjusted to give a movement of about two-thirds of these figures.

A proprietary worm and nut box is connected to the steering wheel by the medium of a universally jointed shaft and connects with a short cross rod and then to substantially longer swinging half-track rods inclined backwards through a considerable angle. There are 2¼ turns from lock to lock.

The frame, which has been developed in collaboration with Messrs. Rubery, Owen, is a unique construction for racing cars. It consists of tubular side-members of 2½ in. diameter, one placed above the other and joined by liberally pierced side plates. A single tube unites the front of the frame and there is a further cross-member immediately ahead of the driver's seat and two more immediately ahead of, and behind, the gearbox. The arrangement gives great beam stiffness, but owing to the comparatively great length of the engine-cum-blower and clutch assembly which is mounted at three points, there is little in the way of transverse stiffening over the front two-thirds of the structure. The weight with brackets was 196 lb.

For Formula I races Girling brakes of the three-shoe type were used, the layout being such that the servo effect provided by each shoe was almost non-existent. This, in conjunction with cast-iron brakes, was intended to produce optimum stability of braking throughout on long-distance events, and although the drums were of only 14 in. diameter and somewhat enclosed within the wheel rims, air circulation was enhanced by the elimination of the usual back plate, the shoes being supported by light alloy spiders. In order to maintain the pedal effort within a reasonable figure, a hydraulic servo motor was driven from the engine to augment the pedal effort.

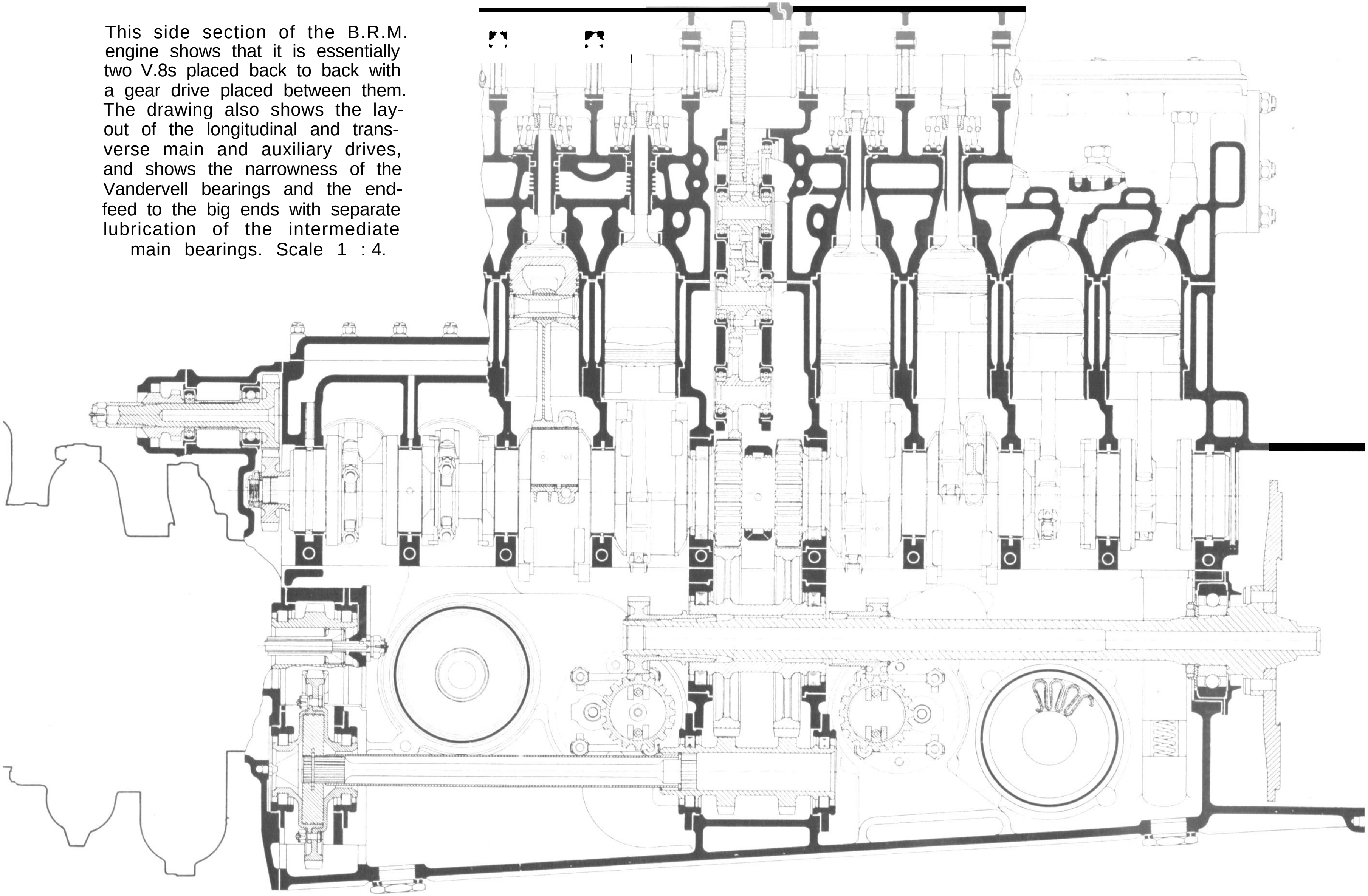
The presence of this servo motor was particularly welcome when it was decided that for the races of 1952 and 1953 the cars should be equipped with Girling disc brakes in place of the orthodox drum type. With this layout a chromium-plated steel disc is pinched by comparatively small diameter pads which are mounted in a light alloy carrier. Three opposed pads are used for each front wheel and two opposed pads for each back wheel, and with this arrangement the brakes themselves have no self-servo effect.

There is a slight saving in unsprung weight, but the most important advantage derived from the change is a virtual immunity from fade, giving complete consistency of braking throughout an event. Another noticeable aspect is very even braking effort, as there are no irregularities caused by drum distortion or eccentric mounting.

Dealing now with the auxiliaries, the light alloy radiator is placed at the extreme nose of the car and below the level of the cylinder heads and the separate offtakes above each combustion chamber are, therefore, connected by a Y pipe on each side of the engine to a pressurised header tank mounted forward of the fire-proof bulkhead. The oil cooling radiator is placed beneath the water cooling core and oil is contained in a four-gallon tank mounted between the engine and the left-hand side-member of the frame.

The fuel is contained in a 15-gallon tank behind the driver's seat, but the main supply of 25 gallons is carried in a saddle-tank formed in the scuttle. Due to the general construction of the car the height is exceptionally low, as is the frontal area, but with the comparatively large brake horse-power available the front air intake has necessarily

This side section of the B.R.M. engine shows that it is essentially two V.8s placed back to back with a gear drive placed between them. The drawing also shows the lay-out of the longitudinal and trans-verse main and auxiliary drives, and shows the narrowness of the Vandervell bearings and the end-feed to the big ends with separate lubrication of the intermediate main bearings. Scale 1 : 4.



to be comparatively large. The whole car had originally, however, a very smooth outline and it is evident that the maintenance of really smooth air flow at high speed had been in the forefront of the designer's mind.

The frontal aspect of the car was changed, indeed one might say mutilated, in 1952 and 1953, in order to increase the air flow through the radiator and beneath the bonnet. The original graceful ellipse at the front end of the car was enlarged to the rectangle shown in the perspective drawing and a substantial air scoop was superimposed.

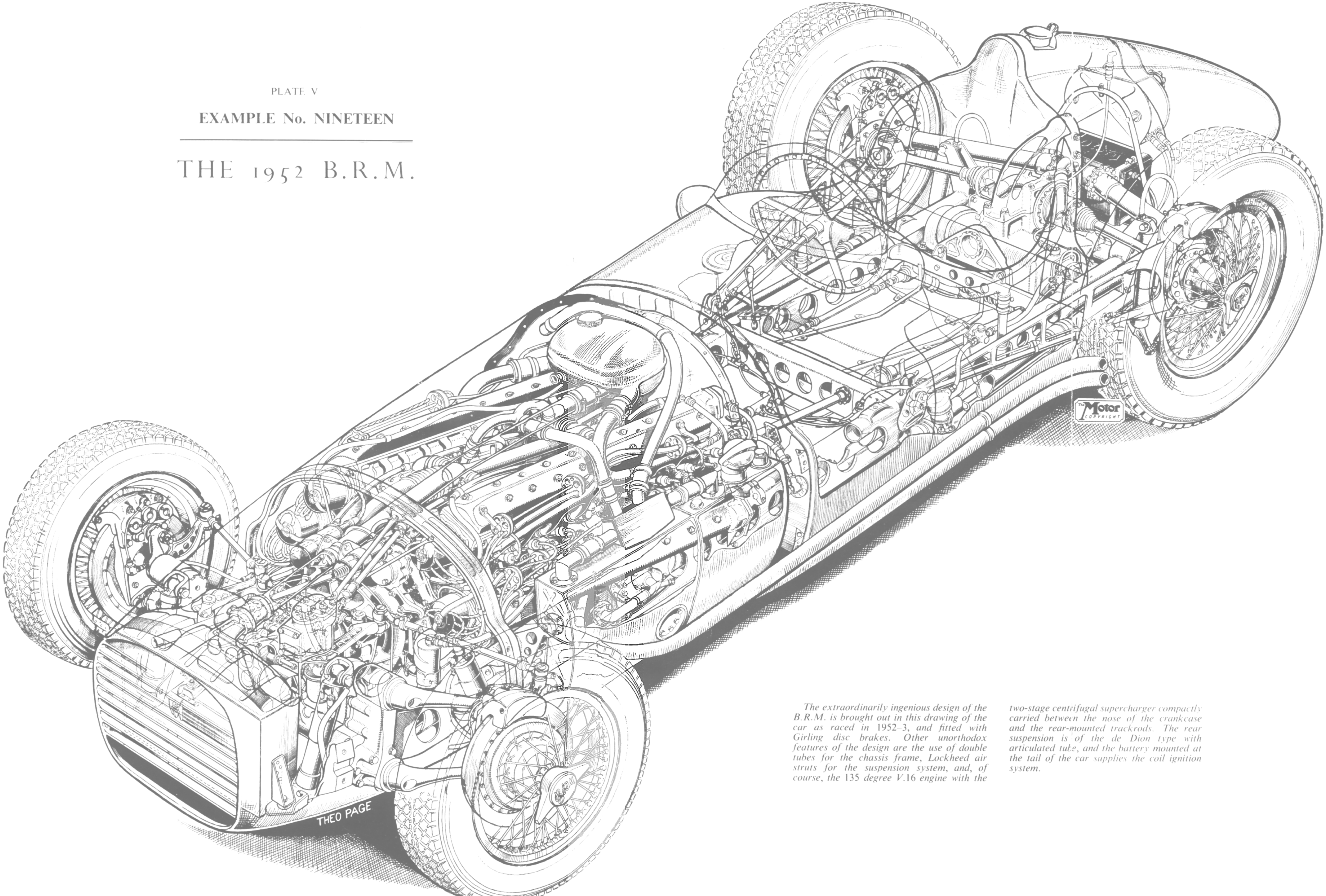
Considerable changes were also made with the exhaust system for the Formula I races of 1950 and 1951. Two pipes leading from the front and back set of four cylinders on each side were merged into one long tail pipe of somewhat smaller diameter. In the next two years experiments with stub pipes had to be abandoned owing to intolerable noise, and a more common arrangement was two separate pipes splayed out and cut off just ahead of the rear wheels. In some cases a single pipe was used for the last foot or two with a bell at the end.

A further mechanical change was the substitution of braced radius rods for the pressings originally used to locate the rear hubs-a modification which did not affect the principles or geometry of the rear suspension.

PLATE V

EXAMPLE No. NINETEEN

THE 1952 B.R.M.



The extraordinarily ingenious design of the B.R.M. is brought out in this drawing of the car as raced in 1952–3, and fitted with Girling disc brakes. Other unorthodox features of the design are the use of double tubes for the chassis frame, Lockheed air struts for the suspension system, and, of course, the 135 degree V.16 engine with the two-stage centrifugal supercharger compactly carried between the nose of the crankcase and the rear-mounted trackrods. The rear suspension is of the de Dion type with articulated tube, and the battery mounted at the tail of the car supplies the coil ignition system.

DETAILS OF CAR AS COMPETING 1950-l *

MAKE.-B.R.M.
TYPE.-Formula I Grand Prix car
YEAR OF CONSTRUCTION.-1949-53
YEARS RACED.-1950-3
DESIGNER.-P. Berthon
WHEELBASE.-8 ft. 2 in.
FRONT TRACK.-4 ft. 4 in.
REAR TRACK.-4 ft. 3 in.
FRONTAL AREA.-9½ sq. ft.
UNLADEN WEIGHT.-16 cwt.
ALL-UP STARTING LINE WEIGHT.-20 Cwt.
MAXIMUM SPEED.-190 m.p.h.
SPEED ON INDIRECT GEARS.-165 m.p.h. on Fourth ; 130 m.p.h. on Third ; 115 m.p.h. on Second ; 95 m.p.h. on First
H.P. PER SQ. FT.-55.2
H.P. PER TON UNLADEN.-535
H.P. PER TON ALL-UP.-430
BORE.-49.53
STROKE.-47.8
STROKE : BORE RATIO.-0.965 : 1
No. OF CYLINDERS.-Sixteen
PISTON AREA.-47.8 sq. in.
B.H.P.-430 at 11,000 r.p.m.
H.P. PER SQ. IN. PISTON AREA.-9.0
B.M.E.P.-340 lb./sq. in.
PISTON SPEED.-3,450 ft./min.
CYLINDER HEAD.-Four detachable light alloy castings
VALVES NO.-Two per cylinder
VALVES ANGLE.-90 degrees
VALVE AREA.-Inlet 19.63 sq. in. ; Exhaust 15.2 sq. in.
CYLINDER BLOCK.-Water jackets formed in one piece with upper half of crankcase with inserted detachable cast-iron liners set at an included angle of 135 degrees
FUEL.-Petrol/alcohol mixture
CARBURETTERS.-Two horizontal S.U.
SUPERCHARGER.-Rolls-Royce two-stage centrifugal
MANIFOLD PRESSURE.-4 ata.
IGNITION.-Lucas coil with four Lucas distributors
PLUGS No.-Sixteen
PLUGS TYPE.-Lodge
PLUGS LOCATION.-Offset on centre line of combustion chamber
CRANKCASE.-Two light alloy castings vertically divided
SUMP.-Single light alloy casting supporting auxiliary and final drives
CRANKSHAFT.-Two-piece, counter-balanced
MAIN BEARING No.-Ten
MAIN BEARING TYPE.-Two roller and eight Vandervell three-layer thin-wall
BIG END TYPE.-Vandervell three-layer thin-wall
LUBRICATION.-Dry sump with four-gallon oil tank and end feed to crankshaft at 50/70 lb./sq. in.
CAMSHAFT LOCATION.-Two o.h.c.s. per cylinder head
VALVES OPERATED.-Through rocking followers
CAMSHAFT DRIVE.-By train of gears
CAMSHAFT DRIVE LOCATION.-Centre of engine
CLUTCH.-Multi-plate mounted on half engine speed sub-shaft driven by gears from centre of crankshaft
GEARBOX LOCATION.-In unit with rear axle drive
GEAR RATIOS.-According to course
TRANSMISSION.-By two-piece propeller shaft to 1 : 1 right-angle drive through all-indirect gears and final spur wheels to two exposed halfshafts with inboard de Dion and outboard Hooke type universal joints
FRAME.-Side-members of double tube with spacers and four cross-members
FRONT SUSPENSION.-Porsche type trailing arms with Lockheed air struts
REAR SUSPENSION.-de Dion axle with split axle tube located sideways by central sliding member with drive and torque reactions contained by single arms located on chassis frame. Lockheed air struts
SHOCK ABSORBERS.-None
BRAKE SYSTEM.-Girling hydraulic servo
BRAKE DRUM DIAMETER.-Girling three-shoe or disc type brake (post-1951)
WHEELS.-Dunlop detachable
TYRES.-Dunlop 5.25 by 18 front ; 7 by 17 rear

* *Vide* Chapter XXII for subsequent statistics.

FORMULA I RACING RECORD B.R.M.

Date	*Event*	*Course*	*Average Speed m.p.h.*	*Lap Speed m.p.h.*
26/8/50	International Trophy . .	Silverstone	(a)	—
29/10/50	Penya Rhin	Pedralbes	(a)	94.9
14/7/51	British Grand Prix . .	Silverstone	90.5 (5th.)	94.5
16/9/51	Italian Grand Prix . .	Monza	(b)	120.4 (P)

(a) Non-Starters.
(b) Non-Finisher.

CHAPTER FIVE

Formula II Cars, 1948-53

VERY often in the history of automobile racing there have been two concerns whose Grand Prix cars have had a considerable degree of superiority over their rivals. In the earliest days Mors challenged Panhard ; in 1907-8 came the battle of Mercedes versus Fiat, followed in 1912-3 by Peugeot versus Delage and in 1914 Mercedes against Peugeot. When Grand Prix racing restarted in 1921 a two-year lead by Fiat gave way to battle between Delage and Alfa Romeo, followed from 1925-31 by Alfa Romeo versus Bugatti, and then between 1934 the great struggle between the two German concerns, Auto Union and Mercedes-Benz. As has been shown in earlier chapters of this volume, post-war Formula I racing was notable for the dominance of the pre-war-designed Type 158 Alfa Romeo, but this model was eventually challenged with success by Ferrari.

In Formula II the story has been somewhat different. From 1948 up to the end of 1953 the mere presence of a Ferrari has set odds of 9 : 1 against a win by any other make, and one can cite but two instances when a team of three works-entered Ferraris has not provided a winning car. From one point of view, therefore, a full description of the 2-litre Ferraris, fitted first with a twelve- and then with the four-cylinder engine, would suffice as a complete technical record of the period. But many other makes have been only a little inferior in speed and a number of the designs have embodied features of considerable engineering interest. On this account, this chapter will give a brief survey of all the principal cars which have competed in Formula II. A further reason for so doing is that it is as yet too early to determine the relative significance of some of the details of design and it will serve the cause of progress best to make brief references to them all.

CONNAUGHT

INTRODUCTION

The four-cylinder Connaught was first put on the track in 1950, but was seriously damaged when being tested during August, and appeared only once at a minor meeting at the end of the year. It reappeared for the season of 1951 with the original, wishbone-type, independent rear suspension replaced by a de Dion rear end.

Six cars were constructed during 1951 and a further four between 1952 and 1953. As might be expected, a number of changes were made in detail design during the three seasons of operation and these are referred to in the notes below on the construction of the car. The Connaught can be shown to be substantially the fastest British Formula II car and it has in all had a record of 20 wins, 23 seconds, and 13 third places.

CONSTRUCTION

Engine

The Connaught engine derived from initial use of a 1½-litre Lea-Francis power unit designed by Mr. Hugh Rose, who was also responsible for the successful 1912

Coupe de l'Auto Sunbeam cars. The original design had a bore and stroke of 69 and 100 mm. and gave 50 b.h.p. at 4,700 r.p.m., and a later development of 1,750 c.c. (75 x 100 mm.) gave 85 b.h.p. at 5,500 r.p.m. Modifications to valve lift, compression ratio and inlet systems produced 135 b.h.p. at 6,000 r.p.m.

After this an aluminium cylinder casting was used, giving 79 x 100 mm. with inserted wet liners, and with the original timing chains replaced by a train of gears and the installation of newly designed connecting rods, crankshafts, valves, sump and flywheel the engine in final form bore only an external, and dimensional, similarity to the original.

The four-throw crankshaft is supported in three main bearings, and conventional connecting rods are used in conjunction with steeply domed, light-alloy pistons giving a compression ratio of 10 : 1. The sump is a small-capacity, light-alloy casting attached to a flange well below the centre line of the crank, a scavenge pump feeding oil back to a separate tank. The cylinder head is unusual in being made of cast-iron, for this material, despite its disadvantages in weight and heat transfer, has the merit of stiffness and stability, and also makes it possible to use large valves seating direct in the head. Valves are set at 90 degrees with a central sparking plug, and operated through rockers and push-rods from two camshafts mounted as high up as possible in the main casting. The shafts are driven by a train of five gears at the front end of the engine.

Considerable attention was given to the use of resonant effects to obtain ram in the inlet system and four motor-cycle-type Amal carburetters drew air from a " box " formed in the side of the bonnet, the purpose of this device being to ensure stable conditions around the air entry and not to offer pressure rise derived from the forward motion of the car. The exhaust system was closely matched against the inlet manifolding and the engine in this form gave 155 h.p. at 5,500 r.p.m., which is equal to 5.7 h.p./sq. in. of piston area and 210 lb./sq. in. b.m.e.p. The maximum b.m.e.p. was achieved at 4,000 r.p.m. at 195 lb./sq. in., and 180 lb., or better, were held over the remarkably wide range of 3,100 to 5,500 r.p.m.

During 1953 one car was experimentally fitted with the American Hilborn fuel-injection system. In this arrangement there are four long air-intake pipes with a conventional butterfly throttle mounted in each close to the cylinder head. Upstream from the throttles are four nozzles receiving fuel from a low-pressure pump, the flow being responsive to throttle position, but not to manifold pressure or engine speed. With the wide mixture strength, variations permissible with alcohol fuel and the small amount of part-open throttle conditions obtaining with a racing car of moderate power, this simple, if crude, system has been found to give excellent results. The weight of the Connaught engine with flywheel is 264 lb.

Gearbox and Rear Axle

No clutch is used, power being delivered direct from the crankshaft to a four-speed Wilson-type pre-selector gearbox. A description of this is included in remarks on the Formula I E.R.A. car (q.v.). The propeller shaft is inclined sharply downwards and an extension passes beneath the bevel-box housing to a pair of spur wheels mounted at the back of the car. This enables a quick choice from one of five final axle ratios to be made. A conventional bevel gear and differential are mounted in the bevel box and drive to the rear wheels is through two open halfshafts each with two universal joints.

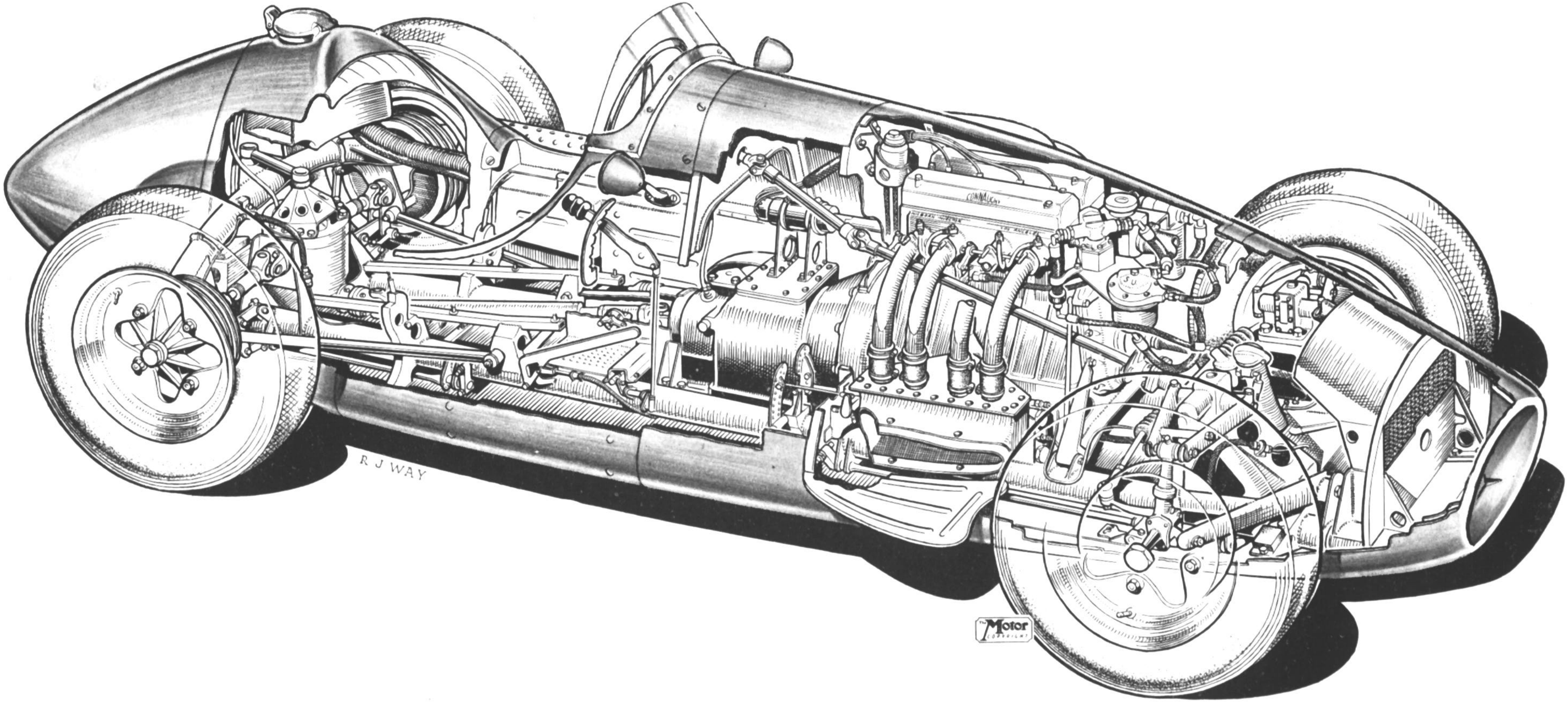


PLATE III

FASTEST FROM ENGLAND – Although designed in the first place to make use of proprietary components, the Formula II Connaught is developed to a point where it became the fastest English car in this class. As can be seen here, a tubular frame supports a de Dion rear axle.system and unequal-length front wishbones, and the four-cylinder engine transmits power to a four-speed pre-selector epicyclic gearbox in which the first gear band is used as a clutch when starting the car from rest.

Rear Suspension

The original design of de Dion layout used an unsplit dead rear axle tube to connect the rear hubs. This was located longitudinally by two parallel radius arms connected both to the frame and to the hubs through rubber bushes. It was inclined inwards in plan view. This arrangement put considerable compression and tension stresses into the radius arms (and hence into the bearings) and was subsequently replaced by longer, single-acting arms attached to the frame with a single torque arm running from a bracket at the mid-point of the de Dion tube to the top of the bevel box, spherical joints being provided at both ends. Simultaneously, the conventional sideways location of the de Dion tube, i.e. with a sliding member in a slot attached to the frame, was changed to transverse-mounted radius arms. Further transverse arms make connection with longitudinally mounted torsion bars in such a manner that there is a rise in rate of 30 per cent at full bump, the roll centre of the rear axle assembly being 5 in. above the ground.

Front Suspension

This is of the double-wishbone type, the lower arms being connected with longitudinally positioned torsion bars. The upper wishbones embrace piston-type dampers and a full-length king-pin is used between the upper and lower links. The wishbones themselves are fabricated from 14-gauge steel and, as originally designed, pave a roll centre 0.4 in. above ground level. Despite the use of a powerful anti-roll bar, the car in this condition tended to over-steer and the elements were subsequently rearranged to bring the roll centre 7 in. above the ground.

Steering Gear

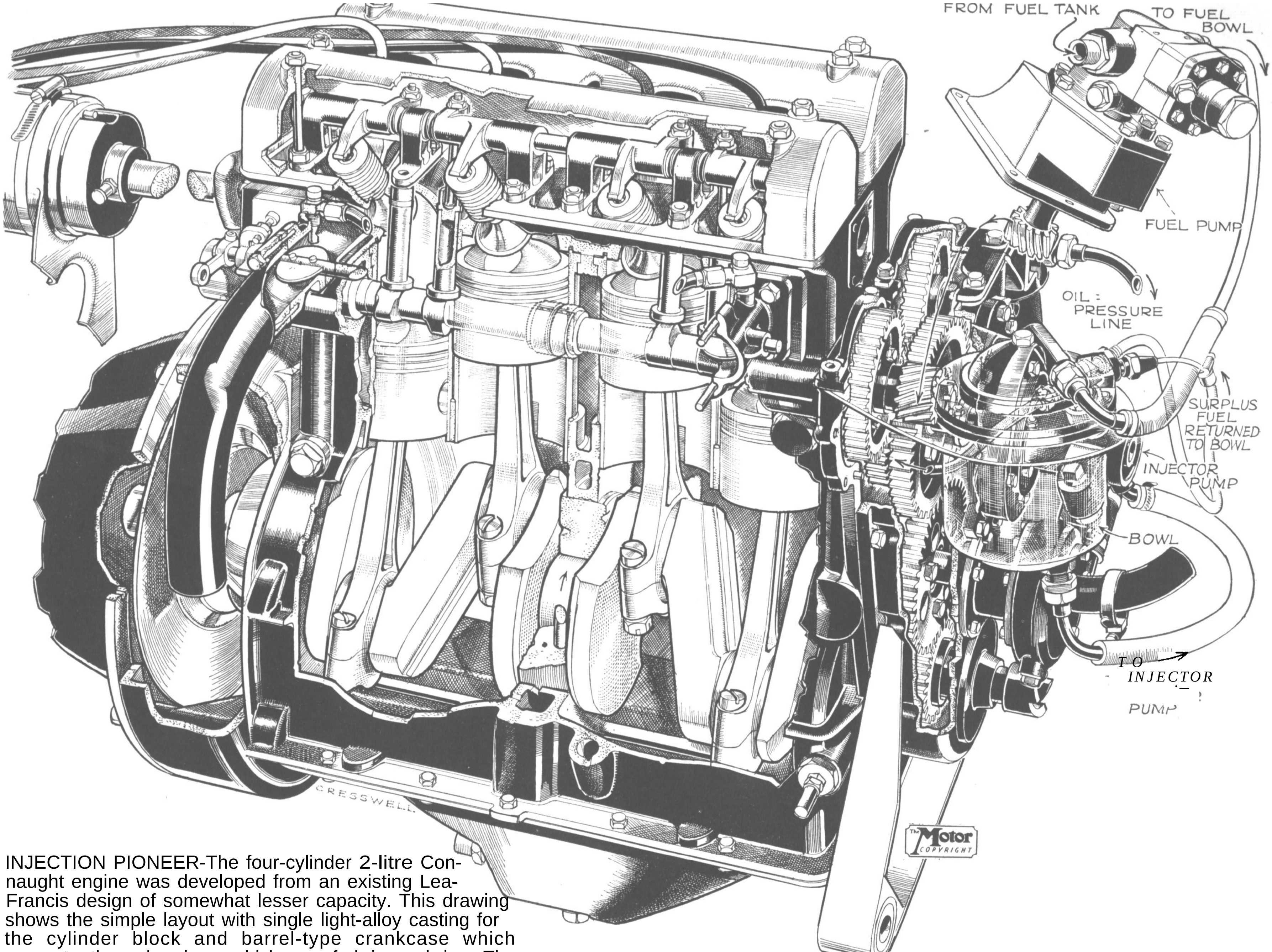
The rack and pinion gear is contained in a light-alloy casting giving two turns from lock to lock with a movement of 25 degrees on the road wheels.

Frame

The frame is based upon two 3¾ in. diameter steel tubes with a wall thickness of 1.6 mm. which converge from front to back-an arrangement originally dictated by the wishbone-type rear suspension used on the prototype. The frame weighs only 90 lb. and is stiffened at the back end by the magnesium casting used for the bevel box and at the front end by a box-section cradle which provides a three-gallon reservoir for the engine oil.

Brakes

Lockheed two leading-shoe brakes are used with a diameter of 12 in. and friction lining area of 181 sq. in. The brakes for front and rear pairs of wheels have independent operating systems connected to the pedal through a whiffle tree which permits any required variation in braking effort between the front and rear wheels. Light-alloy drums with Al-fin liners are used and these also support the unconventional bolt-on disc wheels which are cast in magnesium-zirconium. As originally designed, this arrangement gave an unsprung weight of 62 lb. for each side at the front, and 70 lb. for each side at the back, but on the latest cars the rear brake drum was reduced in size (to 9 in. diameter and l¾ in. wide) and this, together with light-alloy wheel cylinders, gave a weight saving of a little over 12 lb. per wheel.



INJECTION PIONEER-The four-cylinder 2-litre Connaught engine was developed from an existing Lea-Francis design of somewhat lesser capacity. This drawing shows the simple layout with single light-alloy casting for the cylinder block and barrel-type crankcase which supports three bearings which are fed in endwise. The cylinder bores are detachable sleeves and there are two highly-placed camshafts opening the valves through push-rods and rockers. The engine as shown was fitted during 1953 with the American Hilborn-Travers fuel injection system in which mixture is supplied to jets placed upstream of the throttles, flow being varied in accordance with throttle position, but not in relation to engine speed. A fuel bowl guards against aeration, and supplies the pump under constant head.

Body and General Features

From the beginning Connaught pioneered side tanks, one being placed on each side of the car with separate filling systems. The total capacity was 19½ gallons and adequate for non-stop runs in Formula II races originally envisaged as being about 200 miles in length. With greater power, and longer races, it became necessary to enlarge the tanks to ensure a non-stop run and they were at this time made of steel in place of light alloy. On the latest cars the wheelbase was also lengthened to 7 ft. 6 in. (from 7 ft. 1 in.), and the greater weight following from these changes was offset by the use of light-alloy combined radiator and oil cooler weighing only 12 lb. in place of the 42 lb. of the original components.

Although no effort has been made to provide a really aerodynamic shell, the air is ducted carefully through the radiator core and the shape has been made as smooth as possible, even when this has involved slightly increasing the frontal area. The weight of the car in final form was 1,220 lb.

Dimensions qf Connaught

Wheelbase : 7 ft. 6 in. ; Front Track : 3 ft. 10½ in. ; Rear Track : 4 ft. 0½ in.

COOPER

INTRODUCTION

In 1949 the Cooper Co. installed some vee-twin 1,000 cc. J.A.P. engines in a long-wheelbase version of their 500 c.c. Formula III rear-engined chassis. Although possessed of high acceleration, these cars had neither the speed nor the stamina required seriously to compete in Formula II events.

During the winter of 1951-2 it became known that the Bristol Aeroplane Co. were prepared to sell developed versions of the six-cylinder 2-litre engine which had been derived from the Type 328 B.M.W. of 1939 for use in the Bristol saloon car. The Cooper Co. thereupon decided to build a batch of cars using this power unit and to offer them to private owners for the 1952 racing season. At the end of the year the lessons learnt were embodied in a Series II car with greater braking area, a stiffer frame and somewhat lower weight. The Bristol engine used in 1953 developed approximately 150 h.p. compared with about 135 h.p. available during 1952.

CONSTRUCTION

Engine

The six-cylinder engine has a bore and stroke of 66 x 96 mm. and thus betrays the years of its origin by a stroke : bore ratio of 1.45 : 1. The main block is an iron casting in which the six-throw shaft runs in four Vandervell thin-wall bearings, the shaft being heavily counter-balanced. A wet sump is attached to the base of the crank-case and the cylinder head is in light alloy and embodies a number of unusual features.

The 90-degree inclined valves are operated from a single, crankcase-mounted, chain-driven, camshaft, the inlet valves having conventional rockers and the exhaust valves opened through a system of double rockers with short push-rods running in tubes transversely across the head. The high inertia forces inevitable with such an arrangement, and the long stroke of the engine, put a limit on crankshaft speed of below 6,000 r.p.m., but a relatively high power output is obtained through unusually good breathing derived from a unique port layout. Three down-draught Solex carburetters feed mixture into three vertical inlet passages cored into the head, these diverging so that each feeds two inlet valves. There is thus a direct down-flow from the jet to the cylinders, giving exceptional fuelling as indicated by a b.m.e.p. figure of 170 lb./sq. in. on a 10 : 1 compression ratio at 3,620 ft./min. piston speed.

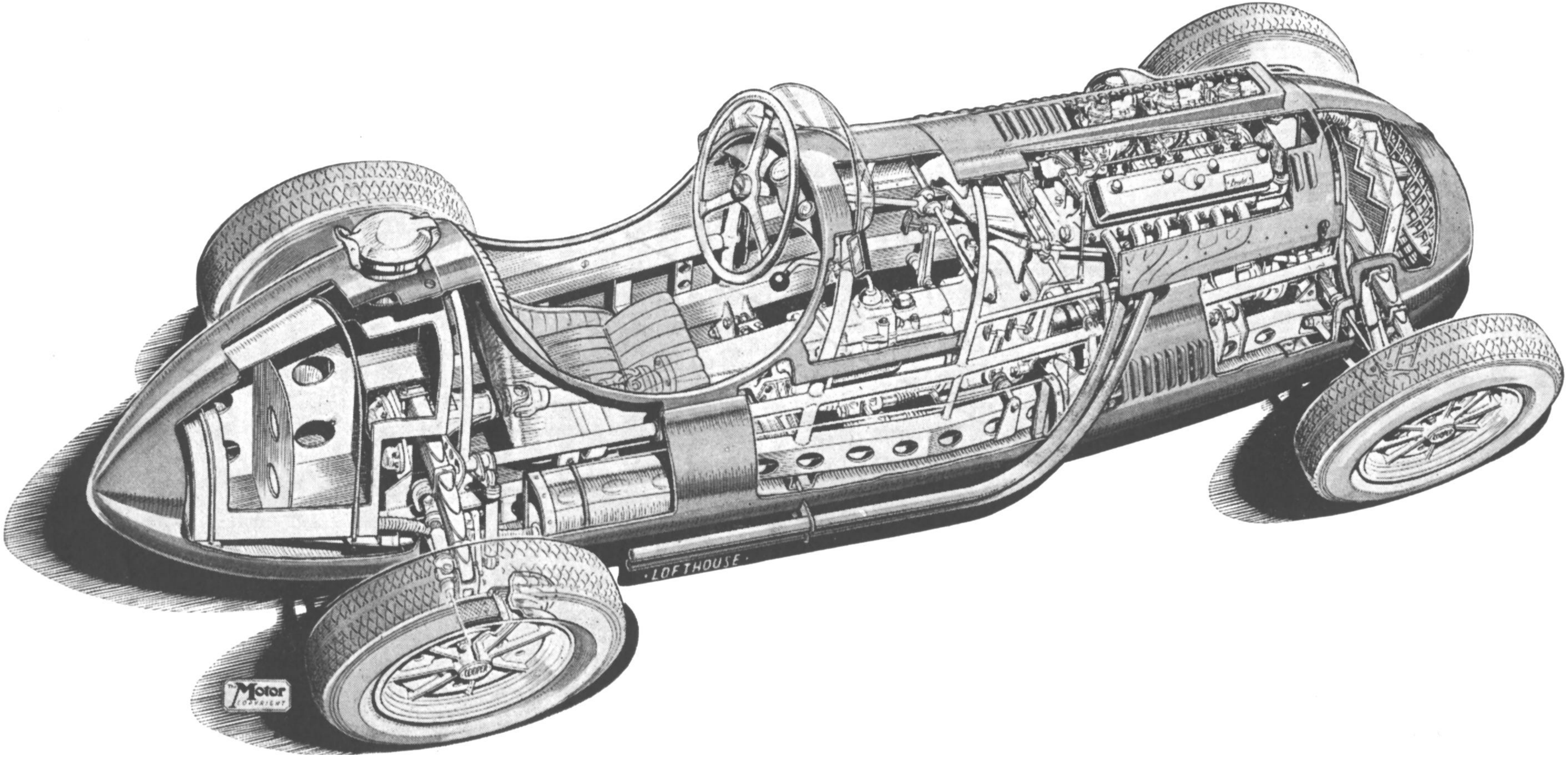
In 1951 the engine was of basically the same design, but with an 8.5 : 1 compression ratio ; the output as originally raised was 120 b.h.p. or 152 Ib./sq. in. b.m.e.p. at 3,460 ft./min. The engine weighs approximately 340 lb.

Gearbox and Rear Axle

A single dry-plate clutch transmits the drive to a four-speed gear train housed in a vertically divided, light-alloy gearbox. From this an open propeller shaft makes a connection with a hypoid rear axle gear mounted in a magnesium alloy casing. On the 1952 models this was bolted between two side plates and had a secondary function of stiffening the rear end of the frame.

Rear Suspension

A single transverse leaf spring also acts as a top radius arm to support the rear hubs. Bottom wishbones having an effective radius equal to the top spring are also used with direct-acting dampers.



EFFECTIVE SIMPLICITY-A batch of Bristol-engined Formula II racing cars built by the Cooper Co. had a good record in 1952, their light weight and reliability compensating for moderate engine power and a simple chassis layout.

The Bristol engines were modified production models giving between 130 and 140 b.h.p. and, as shown here, the chassis was formed from two box-section frame members supporting transverse leaf and wishbone independent suspension fore and aft. The brake drums were cast integrally with the light-alloy front wheels. The 1953 version of this car embodied various modifications, including a space-type frame, separate brake drums and an engine giving 140/150 b.h.p.

Front Suspension

This is, in effect, a replica of the rear suspension and at both front and rear, therefore, the effective roll centre is vertical on ground level, and when cornering both front and rear wheels roll with the car.

Frame

The 1952 cars had box-section frames which were somewhat inswept behind the scuttle. These weighed 150 lb. and, although reinforced by a tubular scuttle and body-mounting structure, were somewhat lacking in torsional rigidity. In 1953 a second batch of cars was made using a space-type frame constructed from 16-gauge steel tubes of 1½ in. diameter. As can be seen from a drawing, these had their maximum depth at the scuttle with two diamond sections running fore and aft.

Steering Gear

A rack and pinion gear is used, the pinion being on the offside of the car, connected to the steering wheel through a double universal jointed open shaft.

Brakes

On the 1952 cars 10 in. diameter Lockheed two leading-shoe brakes with a lining area of 134 sq. in. were cast integrally with the bolt-on light-alloy wheels which have been a characteristic of all Cooper racing cars. On the 1953 models the same type of wheel is used, but with separate Al-fin light-alloy drums. These are 11 in. in diameter, 2¼ in. wide at the front and 1¾ in. wide at the back. Large forward-facing air scoops are provided on the cast magnesium back plates.

General Features

The bodywork on the Cooper has been designed to give the minimum possible frontal area, but on the 1952 cars the high seating position put the driver very high out of the car and thus increased somewhat the drag. On the 1953 models the seat was lowered, and further attention to drag is shown by the split radiator cores. These were joined to a common header tank, but inclined outwards towards their base and air passing through each section did not enter the engine compartment, but was deflected through gills at the outside of the car. A large air scoop was developed on most cars along the top of the bonnet, and some degree of pressurisation in the engine compartment may have been attained.

Dimensions of Cooper

Wheelbase : 7 ft. 6 in. ; Front Track : 3 ft. 10 in. ; Rear Track : 3 ft. 10½ in.

E.R.A. G TYPE

INTRODUCTION

Shortly after the war, financial control of English Racing Automobiles, Ltd., was taken over from Mr. Humphrey Cook by Mr. Leslie Johnson, who was at that time a private owner of one of the E-type E.R.A.s, the parts for which had been constructed in 1939 and assembled immediately following the war.

Despite some theoretical promise, this car could not be developed in time seriously to compete in Formula I racing, and in 1951 it was resolved to make an entirely new start with a Formula II car designed by Mr. David Hodkin, who had been appointed Chief Engineer to the company. A series of unexpected engine difficulties prevented the one car made from figuring prominently in the events of 1952, and at the end of this year the car, and the drawings thereof, was bought by the Bristol Aeroplane Co., Ltd., to further a programme of research upon which they were embarking. Despite the fact that it did not feature in major racing results, the car embodies many features of technical interest which are summarised below.

Construction

The primary design requirement for the G type was to obtain low weight with a high degree of stiffness. The car was also designed as a possible two-seater, so that it could be developed from a racing into a sports-car without major change in layout.

Engine

A Bristol 2-litre engine was chosen, and, with one exception, this was virtually identical with the power units used by Cooper which have been described already.

In order to lower the bonnet line of the E.R.A. as far as possible, a shallow, dry sump was used with a separate scavenge pump. Modifications were also made to the water pump and the 10 mm. sparking plug bosses were modified to permit the use of 14 mm. plugs, the masking normally used being eliminated at the same time.

Considerable efforts were made also to match the flow characteristics of the short down-draught inlet passages with the exhaust system. As can be seen from an illustration of the car, each exhaust port is provided with a separate short pipe, these being gathered together and discharging through a venturi into a single tail pipe. The air intakes to the carburetter were also pressurised by a tightly fitting air box fed by a duct of increasing cross-sectional area, the entry to which was placed at the extreme nose of the car. This gave the equivalent of 0.3 lb. “ boost ” at a forward speed of 120 m.p.h., and the float chambers were, of course, balanced against this pressure.

As installed, the engine gave approximately 150 b.h.p. at 5,500 r.p.m. for a weight of 286 lb.

Gearbox

The flywheel of the engine was bolted direct to a propeller shaft having two Lay-Rub joints, a three-plate 7¼ in. diameter clutch being mounted at the far end of the shaft. Following the clutch was a train of gears giving four speeds, these parts being standard Bristol components giving ratios of 1 : 1.292, 1.824 and 3.611 : 1 respectively. The bevel box was built up with the gearbox with a normal differential, the final axle ratio of 3.54 : 1 being employed for most races.

The transmission aggregate was housed in a casting of magnesium-zirconium alloy, a material widely used throughout the car, as will be described later.

Rear Axle

A de Dion type rear axle is employed, the cross-tube being fabricated from mild steel. In order to ensure a low roll centre at the back of the car, this tube was located by an A-bracket placed below the tube and attached to the base of the bevel box, the outer ends of the tube being located additionally by single trailing arms. As inboard brakes were fitted, the de Dion tube was not subject to torque reactions.

Rear Suspension

Variable-rate coil springs were used at the back with direct-acting dampers, both of these components being mounted at the extreme tail of the frame.

Front Suspension

Fabricated steel wishbones were used at the front end of the car in conjunction with variable rate coil springs which embraced direct-acting dampers. Owing to the use of a frame which was oval in section and formed from a material of low density susceptible to high stress concentrations, considerable thought was given to the distribution of the suspension loads and their transmission into the main structure. As finally used, the near and offside suspension units were combined into a steel assembly which fed only resultant loads into the frame at eight separate points and through specially designed nylon bushes. A similar technique was used where all the other main units were attached to the frame.

Steering Gear

A proprietary rack and pinion steering was used giving 1¾ turns from lock to lock.

Frame

This was one of the most novel features of the G-type E.R.A., which is one of the few cars to have been raced with a non-ferrous frame. Large-diameter magnesium-zirconium tubes were rolled into an oval section, these side-members being reinforced by cross-members placed ahead of the engine, behind the engine, and ahead of the gearbox.

The frame was sharply upswept at the back, this section being provided with a tubular bracing. The fireproof bulkheads, body attachments and so on were mounted on the frame in such a manner that they made no noticeable addition to the stiffness thereof, it thus being possible to use any body shape or type without affecting the basic handling qualities of the car, apart from aerodynamic influence. Although weighing less than 100 lb., this frame gave a stiffness factor of 3,300 lb. ft. degree.

Brakes

Inboard brakes were used at the back end of the car, having a diameter of 12 in. and a shoe width of 2¼ in. At the front end, the deeply finned brake drums were 12 in. diameter with a shoe width of 2¼ in. with two leading shoes.

Wheels

Light-alloy castings were used for the wheels, with detachable light-alloy rims. The spokes of the wheels were arranged to centrifuge air over the face of the brake drum, and the system was virtually immune to fade.

Body and General Features

The fuel was mounted as nearly as possible centrally on the car, the driver being offset to the right-hand side. The low-mounted, light-alloy radiator had a separate header tank and an oil cooler beneath it. The long steering column passing down the right-hand side of the car was of large diameter and made from light alloy.

Somewhat squat and angular in appearance, the G-type E.R.A. was not an attractive car. General layout and special features of the design gave it exceptional road-holding qualities despite an unladen weight of only 10 cwt.

Dimensions

Wheelbase: 8ft.0in.; FrontTrack: 4ft.3in.; RearTrack: 4ft.3in.

THE FOUR-CYLINDER FERRARI

INTRODUCTION

Preceding chapters have demonstrated the dominant position achieved by the Colombo-designed twelve-cylinder Ferraris in Formula II events. In 1951, when it was already apparent that Formula II was likely to be adopted for the Grandes Epreuves of 1952 and 1953, Enzo Ferrari authorised his new chief engineer, Aurelio Lampredi, to develop two new engines. The first of these was a double overhead camshaft twelve-cylinder with a bore and stroke of 62.5 x 52 mm. ; the other an apparent regression in the shape of a four-cylinder with a bore and stroke of 90 x 78 mm. Both of these engines could be fitted into Lampredi's de Dion axle chassis, which became also the basis for the 4½-litre Formula I cars which are described in detail elsewhere.

The Lampredi twelve-cylinder engine was set aside early in 1951 and the four-cylinder type, which was designed and built within three months, dominated the racing of 1952 and 1953.

CONSTRUCTION

Full details of the four-cylinder Ferrari engine are not obtainable, for as the current racing type is similar in many respects to the Formula II model, the manufacturers are naturally reluctant to disclose details which might be of use to possible racing rivals. It is, therefore, necessary to limit this description to the broad features of the power unit and vehicle.

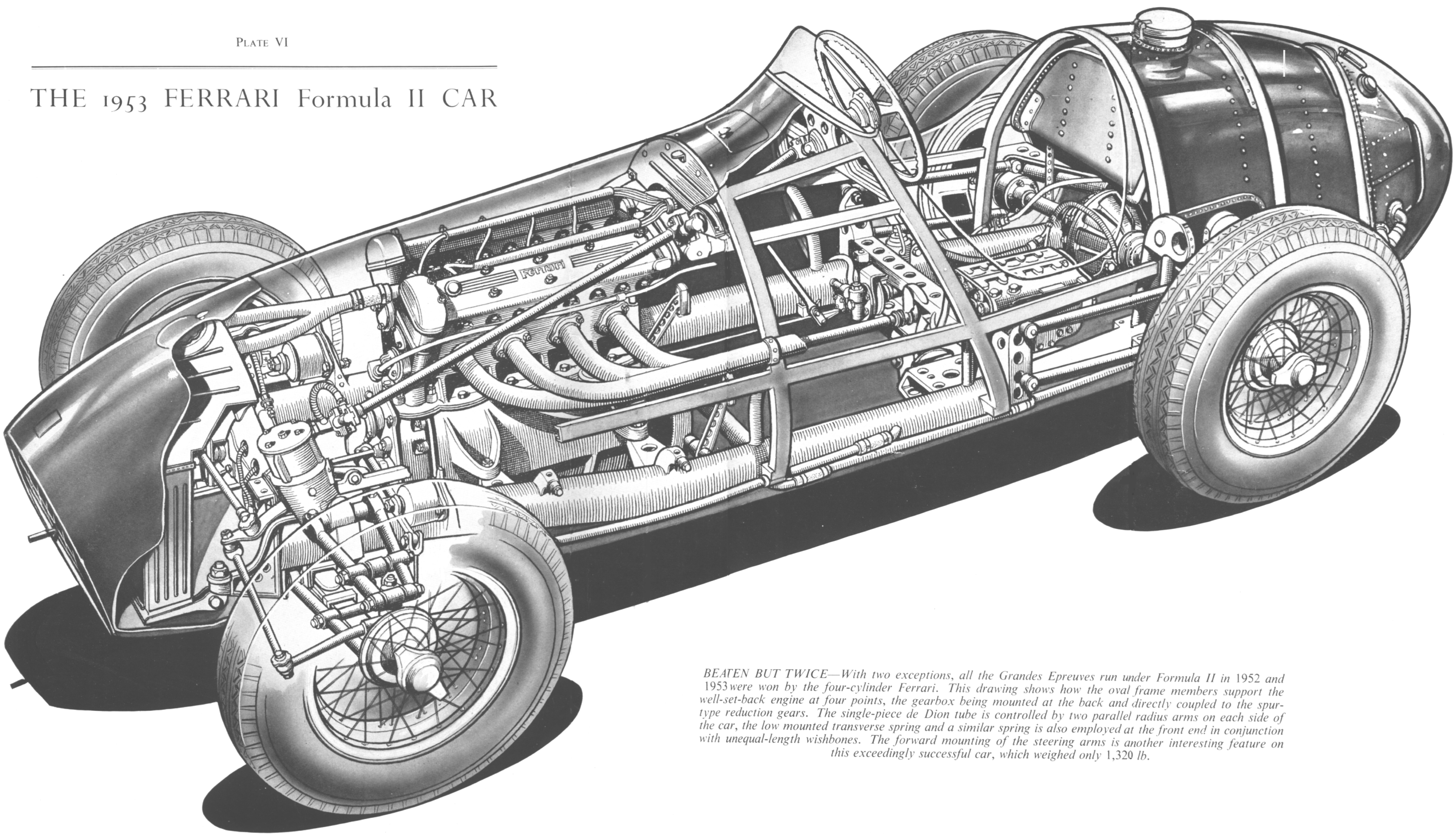
Engine

The basis of the engine is a very deep light-alloy crankcase which provides four mounting points in the frame and also housings for the five Vandervell thin-wall bearings which support the four-throw crankshaft. At the front end of this shaft a train of gears runs upwards to the two overhead camshafts and downwards to the oil and water pumps, and also provides a drive for two magnetos.

The cylinder head is cast integrally with the water jackets but it is open at the base of the hemisphere, for the cylinder bores conventional with this arrangement are made from separate pieces. Four steel liners are provided with a reduced diameter at their upper end and are screwed into a corresponding recess in the combustion chamber. This makes an effective gas and water seal without the use of a gasket, each liner having a flange at the base which traps two rubber rings so as to provide an oil and water joint at the base of the assembly. Although similar in principle to the arrangement used on earlier twelve-cylinder engines, and having in common therewith the advantage that all water passages (including those around the exhaust ports and sparking plug bosses) can be inspected before assembly, this arrangement gives a more reliable joint than the bolted-up construction used on the earlier types, and also enables the cylinder centres to be set more closely together.

Each combustion chamber carries two valves closed by two hairpin springs, the included valve angle being 58 degrees-a figure which is considered to give the best compromise between valve area and shape of combustion chamber with a compression ratio of 12 : 1. Light-alloy inverted tappets are interposed between the camshafts and the valves and they are controlled by double coil springs. Although higher engine speeds can be used, the peak of the engine performance is reached at between 7,000 and 7,200 r.p.m., at which speed the output is approximately 180 b.h.p. This is the

THE 1953 FERRARI Formula II CAR



BEATEN BUT TWICE—With two exceptions, all the Grandes Epreuves run under Formula II in 1952 and 1953 were won by the four-cylinder Ferrari. This drawing shows how the oval frame members support the well-set-back engine at four points, the gearbox being mounted at the back and directly coupled to the spur-type reduction gears. The single-piece de Dion tube is controlled by two parallel radius arms on each side of the car, the low mounted transverse spring and a similar spring is also employed at the front end in conjunction with unequal-length wishbones. The forward mounting of the steering arms is another interesting feature on this exceedingly successful car, which weighed only 1,320 lb.

equivalent of 165 b.m.e.p. at a piston speed of approximately 3,600 ft./min. This excellent figure is the more remarkable in that the engines are run on an 80 : 20 petrol-alcohol mixture which makes possible the fuel consumption of 12 m.p.g. on normal racing circuits.

Considerable gains in combustion efficiency were attained by the use of two sparking plugs per cylinder, these being displaced 10 mm. from the central axis of the head towards the exhaust side, the plugs being screwed in at a slight angle on each side of the bridge between the inlet and exhaust ports.

A number of varying exhaust systems have been tried during the course of two years' racing, that most commonly used having separate pipes from cylinders 1 and 4 and 2 and 3 joined in pairs and then discharging into a common tail pipe.

As on all high-output, unsupercharged engines, much thought has been given to ram effects on the inlet side of the head, and air enters the four choke tubes of the horizontal Weber carburetter through bell-mouthed extension pipes of carefully determined length. Owing to the large size of the combustion sphere and the small alcohol content of the fuel, careful consideration had to be given to internal cooling, and the water pump discharges directly into a passage cored from the centre main bearing, coolant being distributed upwards therefrom to the cylinder head. Water is evacuated from the head by four riser pipes bolted down to passages cored between the dual sparking plug bosses and offset to the inlet side of the head. It is evident that in this system due attention has been paid to the desirability of cooling the centre bearing of a four-cylinder engine with substantial reciprocating masses.

Creditable as is the maximum output of the engine, a feature that has aided greatly on racing circuits has been the very high standard of reliability reached and the fact that the peak of the torque curve was reached at a little under 5,000 r.p.m. This gives the driver a range of about 0.7 : 1 in road speed on any given gear ratio and makes possible a saving in weight and driving effort by the use of a four-speed gearbox in place of the five-speed boxes used on the twelve-cylinder engines.

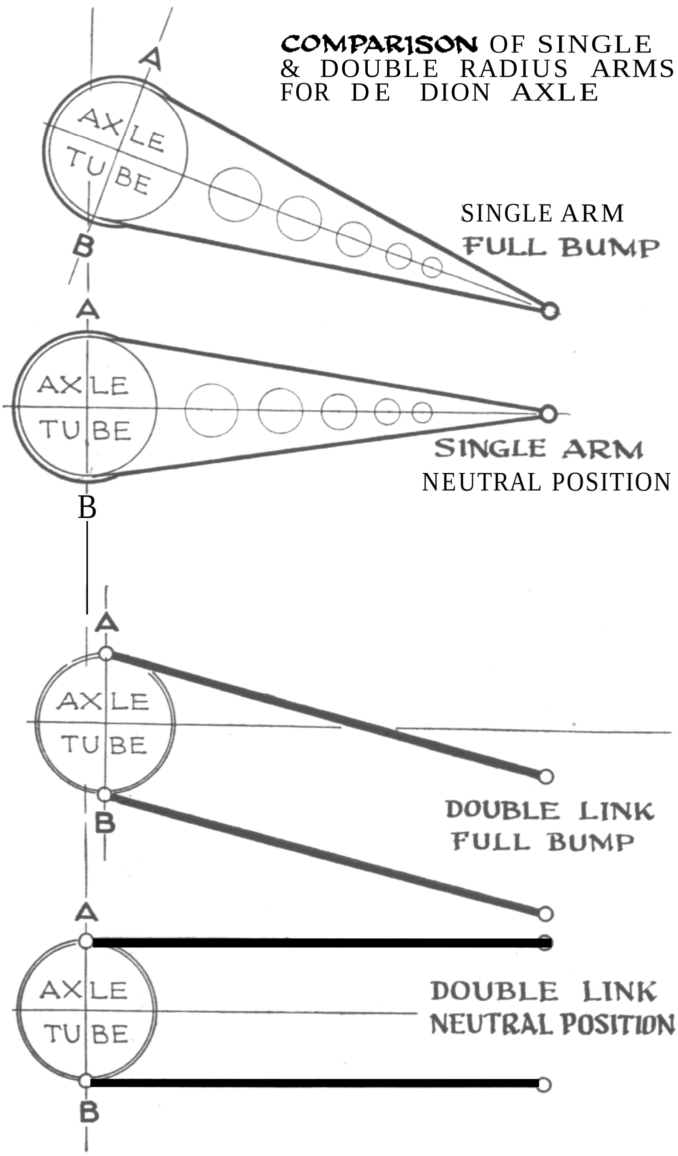
Gearbox

A multi-plate clutch (friction linings alternating with light-alloy discs) transmits power to the four speeds of the box, which are carried in a vertically split light-alloy housing, the main and lay shafts laying side by side and driving a crown wheel and pinion. The vertically split main-drive housing contains two spur wheels which embrace a Z-F limited-slip differential.

Rear Axle

A de Dion type rear axle is used, the tube passing behind the main-drive casting which embodies a groove which provides sideways location for the axle and wheel hubs. As a consequence of using two parallel radius arms on each side of the car, it is not necessary to articulate the de Dion tube, which is a simple steel fabrication.

The Mercedes-Benz 1937 version of the de Dion rear axle, as shown in the illustration overleaf, was widely copied in subsequent years. In this arrangement a cross-tube was given fore and aft location by a single triangulated arm, and, as shown in the two top drawings, if one rear wheel rose there was an angular movement at the end of the axle tube which had, therefore, to be split so as to allow for partial rotation. In 1951 Lampredi introduced an alternative for the Ferrari cars using two parallel



links giving slight variations in wheelbase and angular displacement of the axle tube, but avoiding any rotation thereof. The axle tube could, therefore, be made in one piece with the saving of cost and weight.

Rear Suspension

A transverse leaf spring is placed low down at the back of the car and is damped by two vane-type Houdaille shock absorbers.

Front Suspension

A single transverse leaf spring is mounted very low down at the front end of the frame and was originally connected to the upper member of unequal-length wishbones by an articulated rod. Since mid-1952, the spring, which is provided with two master leaves, has been connected directly to the lower wishbone. A full-length king-pin is placed between the wishbones and a separate link is used to connect with dampers of similar type to those used at the back of the car.

Both front and rear springs are supported at two points, the front location being designed to ensure understeer.

Steering Gear

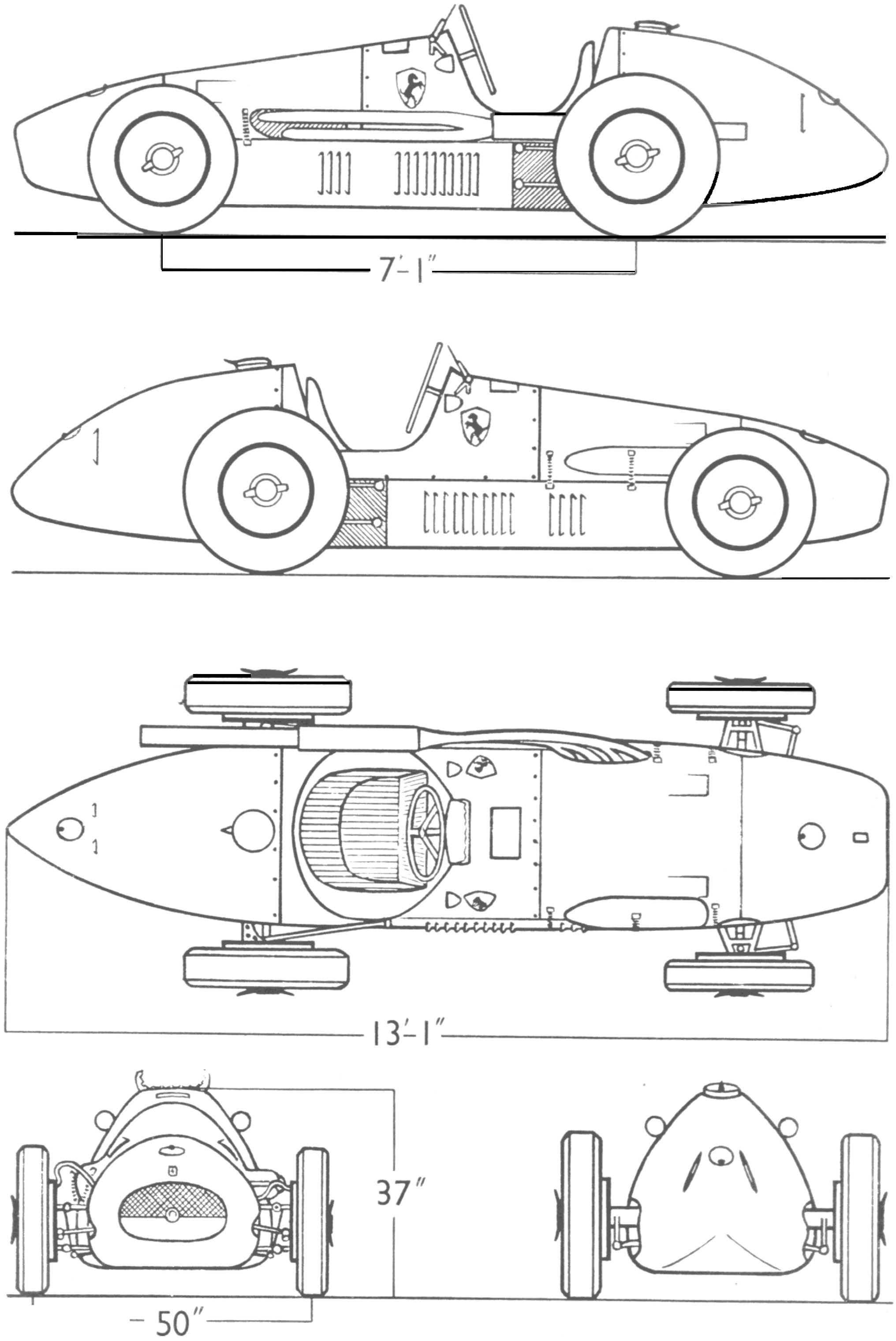
The two-piece steering column passes down the left-hand or exhaust side of the engine and is connected to a worm and wheel steering box through three universal joints. The transverse steering linkage involves a sleeve arm and two short trackrods mounted ahead of the front wheel centres.

Frame

A steel frame is used with oval frame members which are 4.4 in. deep, 2.15 in. wide, and have a wall thickness of only 1.5 mm. This frame is cross-braced by large tubes at the front and back and smaller tubes placed just behind the engine and ahead of the gearbox. A strong arch is also erected around the scuttle and U-section longitudinal tubes are carried fore and aft to give additional stiffness.

Brakes

In order to give the greatest practical diameter for the brakes ; to make possible very deep fins to provide adequate drum stiffness, and to expose the fins to maximum



The 1953 Formula II four-cylinder Ferrari to scale of I : 30.

air flow there is a very marked offset between the wheel centre and the projection of the king-pin. In this respect the car resembles the 4½-litre model, details of which are shown in one of the plates. The light-alloy drums with bonded lining are of 13.8 in. diameter and give a friction lining area of 245 sq. in. Two leading shoes are employed for both front and rear drums, a light-alloy spider attached to the back plate giving a central guiding point for each of the very stiff, light-alloy shoes. In effect, therefore, the system has exceedingly little self-servo action, the higher pedal pressure required as a consequence being deemed preferable to instability of braking with change of lining temperature.

Body and General Features

The Formula II Ferrari is a car of conventional, but well-balanced appearance, the driver being seated centrally above the fixed propeller shaft and the bonnet line falling away sharply to a cowling which carries the air intake very far forward from the front wheel centres. Although the radiator is also considerably outrigged from the nose of the frame, no great effort has been made to reduce the height of the radiator core, and the header tank remains in the conventional position. The tail of the car embraces a 33-gallon fuel tank which weighs but 11 lb., and the all-up weight of the car in 1953 form was only 12 cwt.

Dimensions

Wheelbase 7 ft. 1 in. ; Front Track : 4 ft. 2 in. ; Rear Track : 4ft. 1 in.

GORDINI

As the Formula II Gordini is a direct derivation from the Formula I cars, which have been described in a previous chapter, it is unnecessary to recapitulate the design features item by item.

The power unit has a bore and stroke of 75 x 75 mm., a 1 : 1 relationship which gives a swept volume within 39 c.c. of the maximum allowable under the formula. As on the four-cylinder 1½-litre models, two camshafts run in parallel with a small offset from the longitudinal axis of the engine, the valves being worked by rockers, an interesting revival of the layout used on the 1914 Grand Prix Vauxhall cars. Three double-choke Weber carburetters are bolted directly against the inlet ports cast in the cylinder head, but although the piston area of this engine equals the highest figure utilised in Formula II racing it is generally reckoned, in the absence of authoritative figures from the makers, that the power output is of the order of 160 b.h.p.

As with the four-cylinder version, so with the six, performance was attained by the installation of the power unit into the smallest and lightest possible car. One of the most interesting features of the constant endeavour to " simplicate and add lightness " is the use of single arms for the location of the front wheels, these being free from any triangulated bracing and relying for resistance to brake torque solely upon the very wide bearings on the frame. Exceedingly powerful brakes were fitted to the Formula II Gordinis, a particularly valuable feature being the deep ribbing around the open mouth of the drum with a view to maintaining concentricity. Single leading shoes were used so as to reduce braking instability due to variations in friction lining coefficient with changes in operating temperature.

Gordini was unique in retaining a conventional live axle, and although this was joined to the frame through a link motion, a rear axle hop was a noticeable feature of the cars, particularly when accelerating out of slow corners.

Dimensions

Wheelbase : 7 ft. 6 in. ; Front Track : 4 ft. 2 in. : Rear Track : 4 ft. 2 in.

H.W.M.

INTRODUCTION

The H.W.M. is an interesting example of a car which attained considerable success in the conditions for which Formula II was originally laid down, and then, owing to lack of financial and physical resources, became less successful when Formula II was adopted for the Grandes Epreuves.

The team of H.W.M. cars which entered Formula II racing in 1950 were basically two-seater models each with a four-cylinder Alta engine mounted in a simple tubular frame using an independent suspension front and back with transverse leaf springs and single wishbones. In 1951 the cars appeared as single-seaters with wishbones and coil-type independent front suspension, making use of standard production units used by Morris Motors, the M.G. Car Co. and Alford & Alder, and at the back a one-piece de Dion tube was supported by quarter-elliptic springs and radius arms, the drive being by a standard Salisbury centre-piece bolted to the frame, with a Wilson pre-selector box directly driven from the engine.

When developing about 130 b.h.p., the engine (which was designed in 1944) proved very reliable, but, following a change to Weber carburetters and increased power output, a good deal of engine trouble was experienced, and the cars were also found to be rather overweight compared with their rapidly developing rivals. For 1952, therefore, considerable changes of design were introduced and the cars about to be described are of the 1952-3 type.

CONSTRUCTION

Although designed specifically for racing purposes, financial considerations made it imperative to use the largest possible number of standard parts in these cars, and this overriding consideration made it imperative to compromise between what was known to be the best theoretical practice and that which was physically possible.

Engine

The basic Alta engine design dates back to the pre-war period, and includes many features of considerable interest. The crankcase walls are extended upwards to form the water jackets and the four bores are formed in one cast-iron block held down on to a retaining wall passing horizontally across the crankcase by through bolts which also pull down the light-alloy cylinder head. The top of the block is flanged and has machined in it a recess into which is fitted four Wills pressure rings which form a most efficient joint between head and block.

Two overhead valves, inclined at an included angle of 68 degrees, are operated from overhead camshafts through the medium of rocking fingers, and in the 1952 models these shafts were driven by a chain placed at the back of the engine so as to reduce stresses induced by torsional resonance to a minimum.

The crankshaft, which runs in three main bearings, was redesigned for 1952 by S.Z. Milledge in conjunction with R. R. Jackson. Other changes were simultaneously made to the power unit. The inlet port shape was revised within the framework of the existing head casting, and the camshaft was modified and the lift of the inlet valves increased. Sand-cast Y-alloy pistons, steeply domed to give a compression ratio of 14 : 1, were used and specially designed connecting rods were employed.

The result of these changes was to increase the power output by rather more than 10 per cent, and, more important, to increase the maximum permissible engine speed from 5,000 to 6,000 r.p.m. and thus to extend the road speed range possible in any given gear ratio.

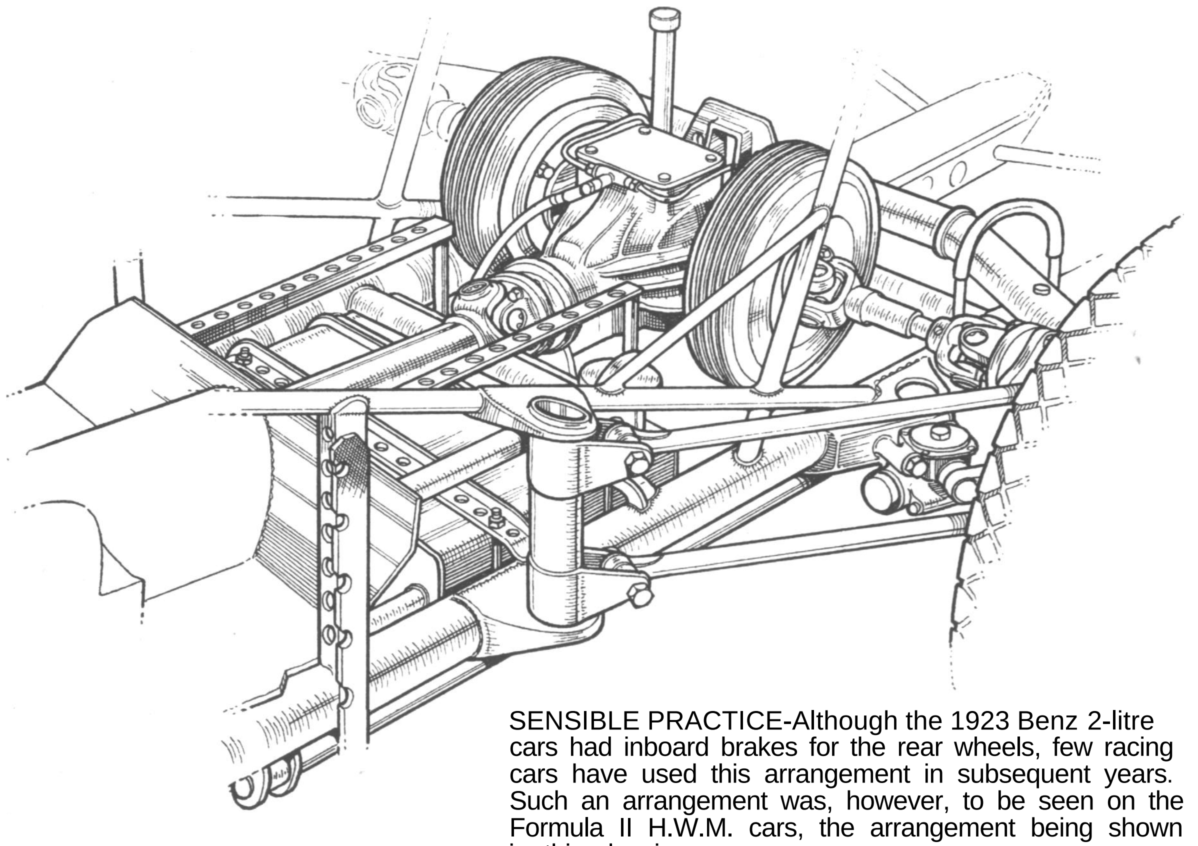
For 1953 considerably greater power output was sought without changing the bore and stroke of 83.5 x 90 mm. An entirely new cylinder head was designed by Weslake, the overhead camshafts being driven from a train of gears at the front of the engine. In this form the output was 160 b.h.p. at 6,000 r.p.m. using a 12 : 1 compression ratio, this being the equivalent of 173 b.m.e.p. at a piston speed of 3,550 ft./min.

Gearbox

The 1952 cars, in common with their predecessors, used the Wilson pre-selector type gearbox giving indirect ratios of 1.21, 1.5 and 2.0 : 1. The bottom-gear bands were also used to take up the drive when starting from rest. Some difficulties were experienced in maintaining these gearboxes in a reliable state under racing conditions, and in 1953 a conventional clutch was used in conjunction with a Jaguar XK 120C gearbox giving the unfortunately wide ratios of 1.36, 1.99 and 3.46 : 1.

Rear Axle

On the 1952-3 models the chrome-molybdenum de Dion tube was located by a central guide, fore and aft location being provided by two parallel tubes on each side of the car, somewhat sharply inswept to a locating point on the rather narrow tubular frame. With the unsplit de Dion tube originally employed, this layout led to excessive



SENSIBLE PRACTICE-Although the 1923 Benz 2-litre cars had inboard brakes for the rear wheels, few racing cars have used this arrangement in subsequent years. Such an arrangement was, however, to be seen on the Formula II H.W.M. cars, the arrangement being shown in this drawing.

roll stiffness at the rear end of the car, and to over-steering. In 1953 the tube was divided with a notable improvement in handling characteristics. The weight of the axle and radius arms was 46 lb. The rear brakes were mounted inboard adjacent to the fixed bevel box and the rear axle was not required to contain braking torque. For 1953 a new design of bevel box was used with quick-change spur gears so that overall axle ratios could readily be modified without changing the whole unit.

Rear Suspension

A link gear connected the de Dion tube to a torsion bar placed beneath the frame.

Front Suspension

This was continued basically unchanged with open-coil front springs and piston-type dampers incorporated in the bearings for the top wishbones. A front anti-roll bar was fitted.

Steering Gear

A proprietary rack and pinion steering gear was employed connected to the steering wheel through a three-piece steering column.

Frame

In 1952 the 2½ in. 16-gauge steel frame was given additional beam and torsional stiffness by a triangulated bracing of much smaller diameter tubes which provided also a convenient support for the body shell. The weight of the total frame structure, including the body supports, was 132 lb.

Brakes

Girling hydraulic brakes were employed, the drum width being 2 in. at the front and 2¼ in. at the back, the diameters being 12 in. and 11 in. respectively, and the drums of the Wellworthy Al-fin type. An interesting detail is the back plate for the drums, which is made in two parts, the dished centre section being a light-alloy casting to which a steel rim is bolted.

Body and General Features

In order to reduce over-steering tendencies to a minimum and to avoid changes in weight distribution during the course of the race, two side tanks were fitted between the fire wall and the rear wheel. These gave a capacity of 11 gallons and were supplementary to a 21½-gallon rear tank giving a total of 32½ gallons for a weight of 38 lb. Unfortunately, the engine characteristics were such that this was not sufficient to provide a non-stop run through the distances used for the Grandes Epreuves.

The relatively long stroke of the engine resulted in a somewhat high bonnet line, and, owing to the height of the radiator core, the front cowling was not swept down so sharply as was the case with the majority of Formula II cars. The centrally positioned driver was also somewhat highly seated, and it is likely that the wind resistance of the cars was slightly above average for these two reasons.

Dimensions

Wheelbase: 7ft.9in. ; FrontTrack: 4ft.1in. ; RearTrack: 4ft.1in,

MASERATI

During the life of Formula I a large number of successes were secured by the four-cylinder Maserati cars, the design of which could be traced back directly to the Type 4CL with four valves per cylinder which entered competition in 1939. In 1948 the interests of the Maserati brothers were bought by the Orsi family and subsequent modifications to their designs were undertaken by the engineers Massimino and Bellentani. Apart from changes to the engine, a tubular chassis was introduced and the original equal-length wishbones connected to torsion bar springs were replaced by unequal-length wishbones supported by small coil springs compressed by a rocker extending from the top wishbone arm.

The characteristic double-drop arm and independent steering to both wheels was also discarded in favour of the more conventional arrangement. With the advent of Formula II a few of these cars were modified to bring the engine capacity up to 2 litres, with the simultaneous removal of superchargers, but these were private ventures and the factory concentrated upon design and construction of a new engine which would fit into a slightly modified chassis. This, the Type A6GCM, is the subject of the present description.

INTRODUCTION

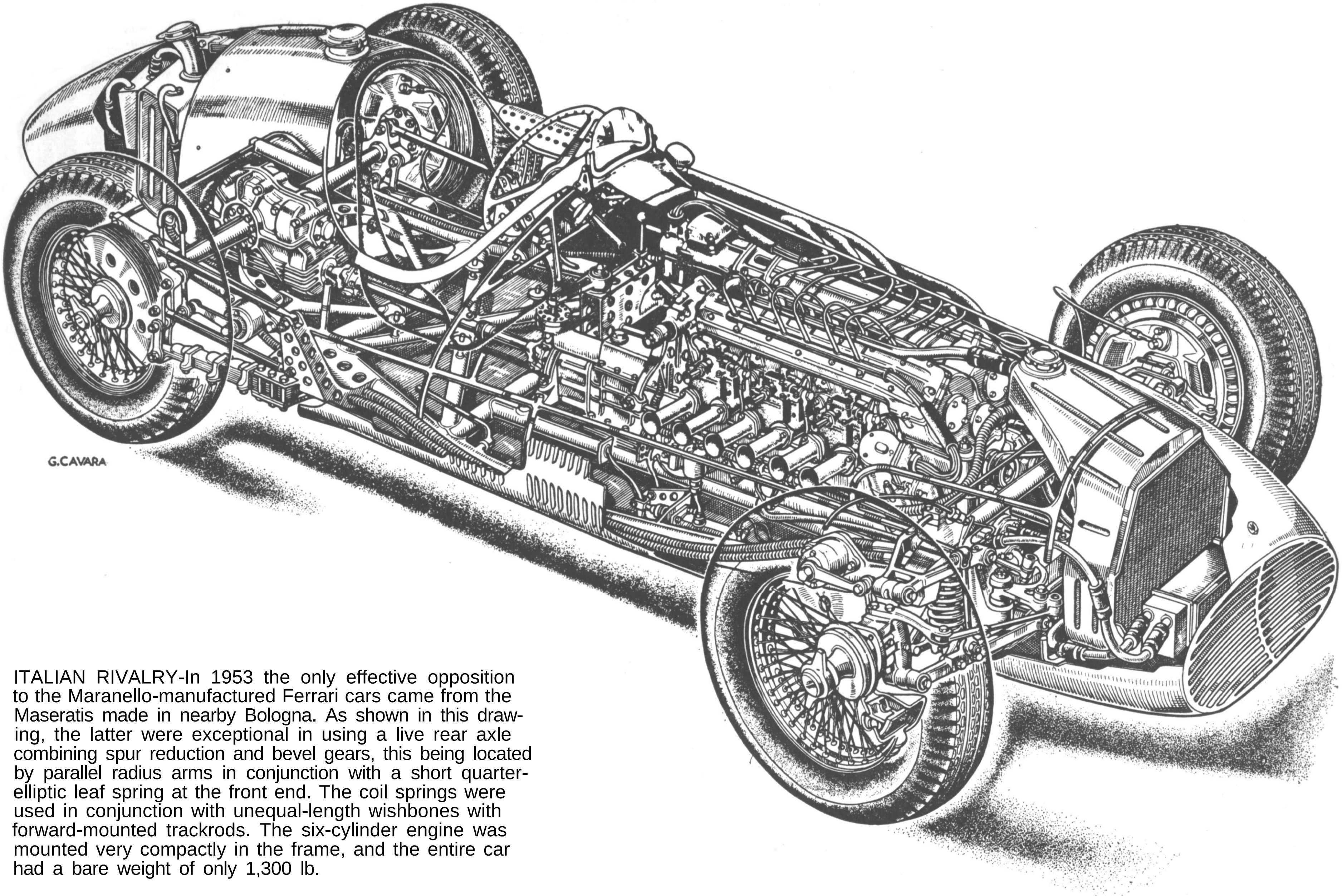
Introduced, and first raced, in 1952, the six-cylinder Maserati benefited in the winter of 1952-3 from the employment of Gioiacchino Colombo, who made extensive revisions to the design of both chassis and engine. The latter raised the output to a point where it can be said with some confidence that the Maserati had the highest maximum speed of all Formula II cars, the performance on a circuit being, however, restricted by continued use of a live rear axle.

Engine

The 1952 engine was based upon an original 1947 Maserati design (the A.6) for a sports-car engine with six cylinders having a bore and stroke of 66 x 72.5 mm. using a single chain-driven camshaft. The detachable cylinder head was completely redesigned for the racing type so as to provide inlet and exhaust valves at an included angle of 90 degrees with overhead camshafts driven from a chain of gears at the front of the engine. Simultaneously, the bore was enlarged and the stroke reduced to give dimensions of 75 x 75 mm. and a piston area of 41.1 sq. in.

The seven-bearing crankshaft runs in a light-alloy crankcase split in the traditional Maserati fashion on the centre line of the crankcase so that the plain bearings are supported by both top and bottom halves. The H-section connecting rods, on the other hand, represent a departure from pre-war Maserati practice, which uniformly favoured tubular rods. A gear-type oil pump at the front end of the engine feeds the main bearings through an external oil pipe mounted on the right-hand side of the crankcase and the dry sump (or, more properly, the lower half of the crankcase) is reinforced by longitudinal cooling ribs.

The light-alloy cylinder head carries the camshafts in seven bearings, the valves being opened through rocking followers hinged upon the inside of each camshaft tunnel. Three double-choke Weber carburetters are fitted to the six inlet ports on the right-hand side of the engine, the exhaust pipes being grouped in pairs of three on the



ITALIAN RIVALRY-In 1953 the only effective opposition to the Maranello-manufactured Ferrari cars came from the Maseratis made in nearby Bologna. As shown in this drawing, the latter were exceptional in using a live rear axle combining spur reduction and bevel gears, this being located by parallel radius arms in conjunction with a short quarter-elliptic leaf spring at the front end. The coil springs were used in conjunction with unequal-length wishbones with forward-mounted trackrods. The six-cylinder engine was mounted very compactly in the frame, and the entire car had a bare weight of only 1,300 lb.

left-hand side of the car. In 1952 a single magneto was driven by right-angle gears from the nose of the crankshaft, being canted outwards to the right-hand side of the car so that the contact breaker and distributor were fully accessible. In this form, and with a compression ratio of 8 : 1, the engine gave 165 b.h.p., and during the course of the 1952 season this figure was raised to 177 b.h.p. using a compression ratio of approximately 14 : 1.

Following the arrival of Colombo at the works, and consequent detail changes introduced between September, 1952, and the beginning of the 1953 season, the peak of the power curve was raised to 8,000 and the placard speed to 8,600 r.p.m. At the peak of the curve 190 b.h.p. was realised, the equivalent of 154 p.s.i., as the b.m.e.p. figure at approximately 3,800 ft./min. The most noteworthy change was an increase in the cylinder bore to 76.2 mm. (and a corresponding enlargement of the piston area to 42.4 sq. in.), the stroke being simultaneously reduced to 72 mm. to keep within the 2-litre limit. Compression ratios were varied during the season between 12 and 15 : 1 (13.75 : 1 being normal), the use of very high ratios being facilitated by the unusual shape of the cylinder head. Taking a section along the longitudinal axis, the combustion chamber is shaped like a bowler hat, there being a pair of projecting plateaux in which the sparking plug bosses are formed. This arrangement is a development of a scheme used on the high compression heads of the Indianapolis Offenhauser engines and is particularly appropriate to the use of dual ignition, which was a further Colombo modification. Bench tests show that this feature in itself was worth 11 b.h.p. net, or 5 per cent of the total.

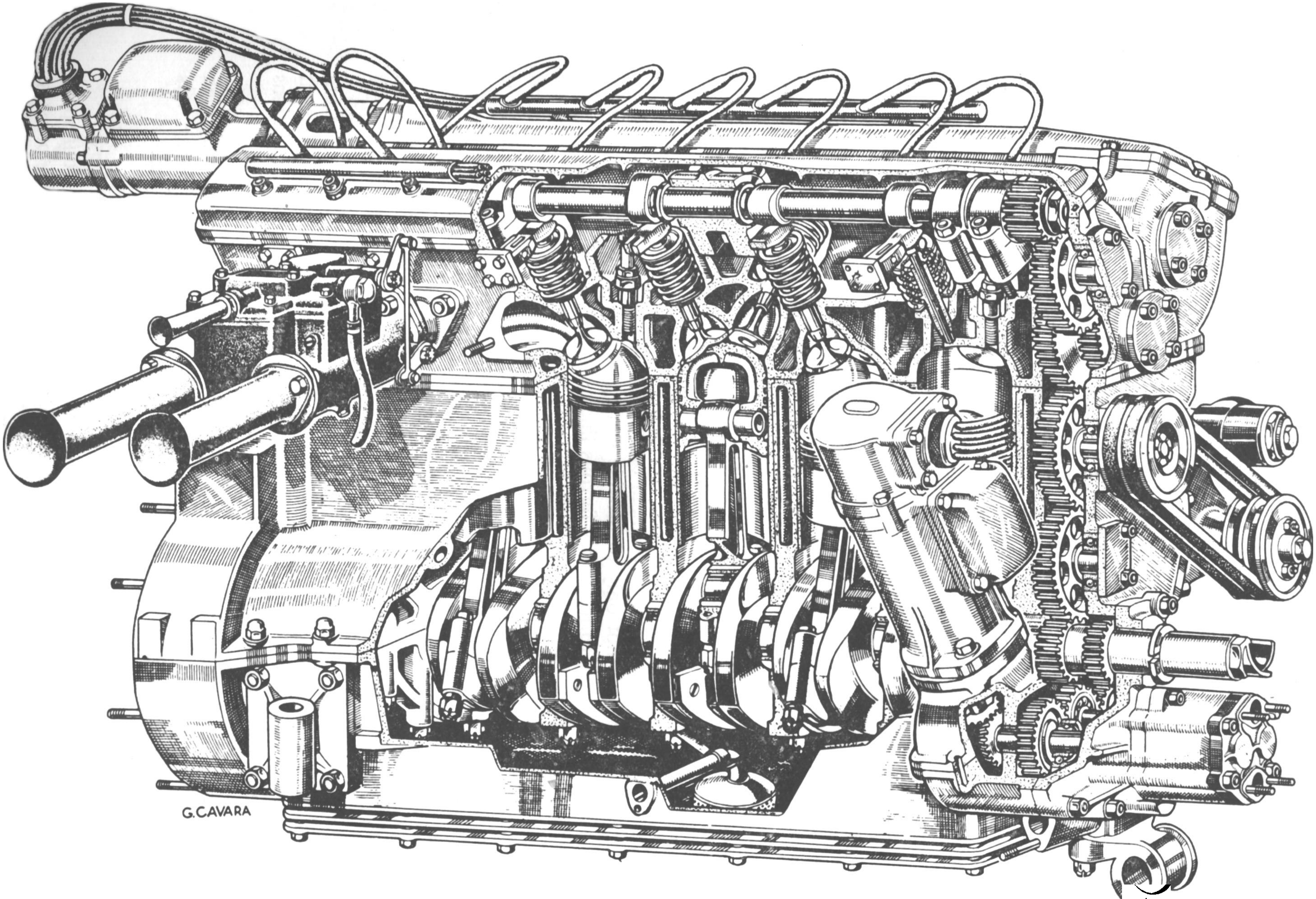
Following upon the use of seven main bearings, the cylinder centres were widely spaced, making it possible not only to provide water passages between each cylinder but also making it possible to insert dry ferrous liners flanged at the top end into the light-alloy cylinder block. The cooling of the cylinder bores was kept entirely separate from the head, and a drawing shows that ample water space was provided both around the valve seats and the sparking plug bosses. This illustration also shows that the camshafts were supported in four bearings with the intermediates placed between cylinders 2 and 3, and 4 and 5, the drive being through a train of five intermediate spur gears to each shaft with the water pump driven by twin belts mounted on the exhaust side of the engine, and the oil pump driven by gears placed directly beneath the nose of the crankshaft.

Being an adaptation, it was found necessary to drive the second magneto from the rear of the exhaust camshaft, but this was recognised as a temporary expedient pending the introduction of a layout which would not be so liable to provide variations in ignition timing as between one magneto and the other.

The peak of the torque curve of this engine was reached at the extremely high figure of 7,000 r.p.m. The greater engine output as compared with the Ferrari was therefore somewhat offset by the lesser range of useful r.p.m. in any given gear.

Gearbox

A double dry-plate clutch takes the drive to a central-positioned four-speed gearbox giving indirect ratios of 1.19, 1.57 and 2.5 : 1. A pump provided pressure lubrication.



MAXIMUM POWER-The Maserati, with six cylinders (76.2 x 72 mm.), was the most powerful engine built for Formula II racing in 1953. Features shown here are the formation of the bearing housings in the top and bottom halves of the crankcase, the use of dry cylinder liners in the light-alloy casting, and the provision of dual ignition from magnetos placed at opposite ends of the engine. The long extension pipes to the individual Weber choke and jet assemblies are used to give ram effect in the upper part of the speed range. The weight was 330 lb. or I .74 lb./h.p.

Rear Axle

The Maserati shared with Gordini the doubtful distinction of being the only Formula II racing car to continue using a live rear axle. The line of the central open propeller shaft was lowered by spur reduction gears placed on the nose of the bevel housing which was split on the centre line. The axle tubes were bolted to each side of the light-alloy housing, there being little change from long-established Maserati practice in this feature.

Rear Suspension

The rear axle was sprung on quarter-elliptic springs splayed outwards on the early models, but maintained as straight extensions of the tubular frame in the Colombo redesign. The springs were connected to the frame through a massive light-alloy casting which also formed an outrigger for a radius arm mounted above the spring and working on the same effective radius so as to provide a true parallelogram movement. At the end of the season upper and lower radius arms were used and at all times the axle was held laterally by an A bracket mounted on the bevel box.

This was almost identical in layout with the original Maserati design for the 1½-litre A6 model which had open coil springs lying between unequal-length wishbones, the lower of the pair having a radius of 7.4 in. and the upper 4 in. In the 1953 manifestation anti-roll bars were used for front and back suspension, as were Houdaille vane-type dampers.

Steering Gear

A worm and wheel steering box mounted behind the engine is connected to a long push-pull rod running along the right-hand side of the crankcase. This, in turn, is connected to a central-mounted bell crank with two half trackrods running out to the front wheels and placed ahead of the wheel centres.

Frame

This, again, was directly derived from the A6 model and consists of two parallel tubes of chrome-molybdenum steel having a diameter of 3.15 in. and a wall thickness of 1.5 mm. A tubular cross-bracing is also provided, this being in the form of a distorted X with a cross-over point nearer to the back than to the front of the car. Colombo increased the inertia of this frame by adding a triangulated construction above the main tubes with heavily perforated strip stiffening the centre section of the car and forming a support for the body.

Brakes

Two leading shoe brakes were used, the drums being of light alloy with a shrunk-in ferrous liner. The rear brakes had conventional circumferential finning but at the front transverse fins of rather coarse pitch were employed. All four drums had an internal diameter of 13 in. and provided for a shoe width of 2.35 in.

Body and General Features

The Maseratis were characterised by a rather high tail which provided, to some extent, a fairing for the driver’s head, the driver in turn being seated lower than on some other Formula II cars. This tail enclosed a fuel tank carrying 28½ gallons, also an oil tank carrying 3.3 gallons, but the high compression ratio used in the engine forced the use of fuel with a high alcohol content and, with a consumption of approx-

imately 8 m.p.g., the rear tank was not sufficient to give a non-stop run ; and when full the weight of fuel (approximately 200 lb.) impaired controllability of the car. In some races an additional tank was provided on the right-hand side of the driver.

Under the Colombo regime the front cowling of the Maserati was extended somewhat and an elliptical air entry was used so that the 1953 cars differed markedly in appearance from the 1952 models.

Dimensions

Wheelbase : 7 ft. 6 in. ; Front Track : 4 ft. 2 in. ; Rear Track : 4 ft. 2 in.

STATISTICS FOR RACING CARS, 1952-3

	1949 *Ferrari*	*1953 Ferrari*	*Connaught*	*H. WM.*	*Maserati*	*Cooper*	*Gordini*
Cylinders	12	4	4	4	6	6	6
Bore M/M	60	90	75	83.5	76.2	66	75
Stroke M/M	58.8	78	100	90	72	96	75
S/B Ratio	0.98	0.87	1.33	1.08	0.95	1.38	1.0
Engine Capacity CM^3	1,992	1,980	1,767	1,960		1,971	1,980
B.H.P.	155	180	155	160	190	150	155
R.P.M.	7,000	7,000	5,500	6,000	8,000	5,750	7,000
B.H.P. per litre	77.5	90	87	70	95	75	77.5
B.M.E.P. lb./sq. in.	145	165	210	173	155	170	149
Piston speed f.p.m.	2,700	3,800	3,600	3,500	3,800	3,620	3,500
Piston area sq. in.	52.5	39.5	27.4	33.9	42.4	31.8	41.1
H.P. per sq. in. piston area ..	3.24	4.55	5.7	4.25	4.5	4.7	3.78
Piston area sq. in. per litre ..	26.25	19.75	15.35	17	21.7	16	20.6
Induction system	1 ata.	1 ata.	1 ata.	1 ata.	1 ata.	1 ata.	1 ata.
Weight unladen (cwt.)	12.5	12	11	12	11.5	10	9
Weight with crew and fuel (cwt.) ..	16	16	I5	16	16	14	13
Engine litres per laden ton	2.5	2.5	2.4	2.5	2.5	2.85	3.16
Engine B.H.P. per laden ton ..	212	225	194	175	235	214	237
Maximum road speed ; m.p.h. ..	145	148	140	130	150	130	140

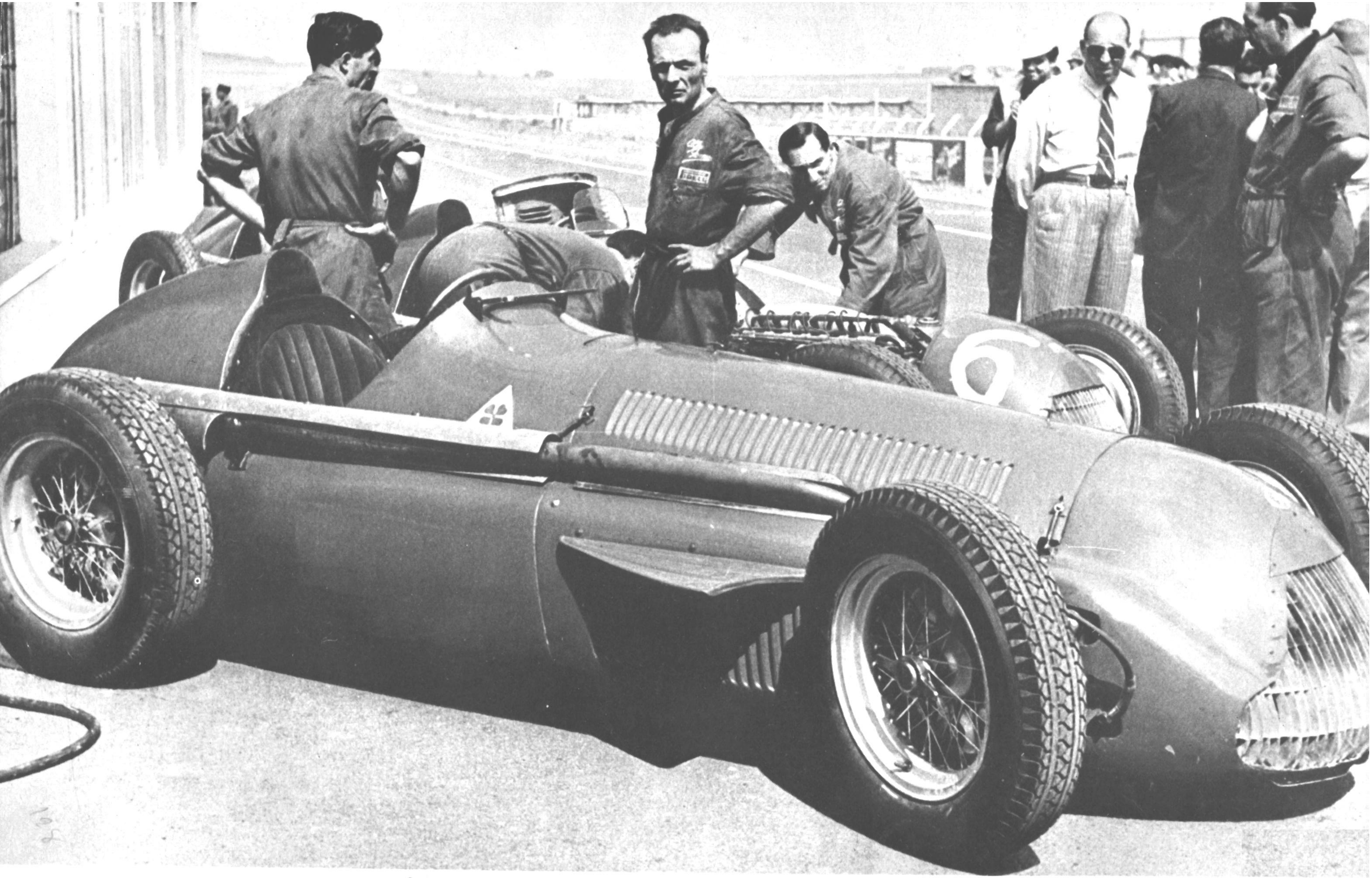


PLATE VII

UNRIVALLED RECORD-The 1½-litre supercharged Alfa Romeo Type 158/9was designed in 1937 and raced between 1938 and 1940. In the post-war Formula I racing it competed during the seasons of 1947, 1948, 1950 and 1951, and out of a total of ninety-nine cars starting in thirty-five events the racing record of the team showed thirty-one victories, nineteen seconds, fifteen thirds, and twenty-three fastest laps. This represents an achievement unparalleled in motor racing history.

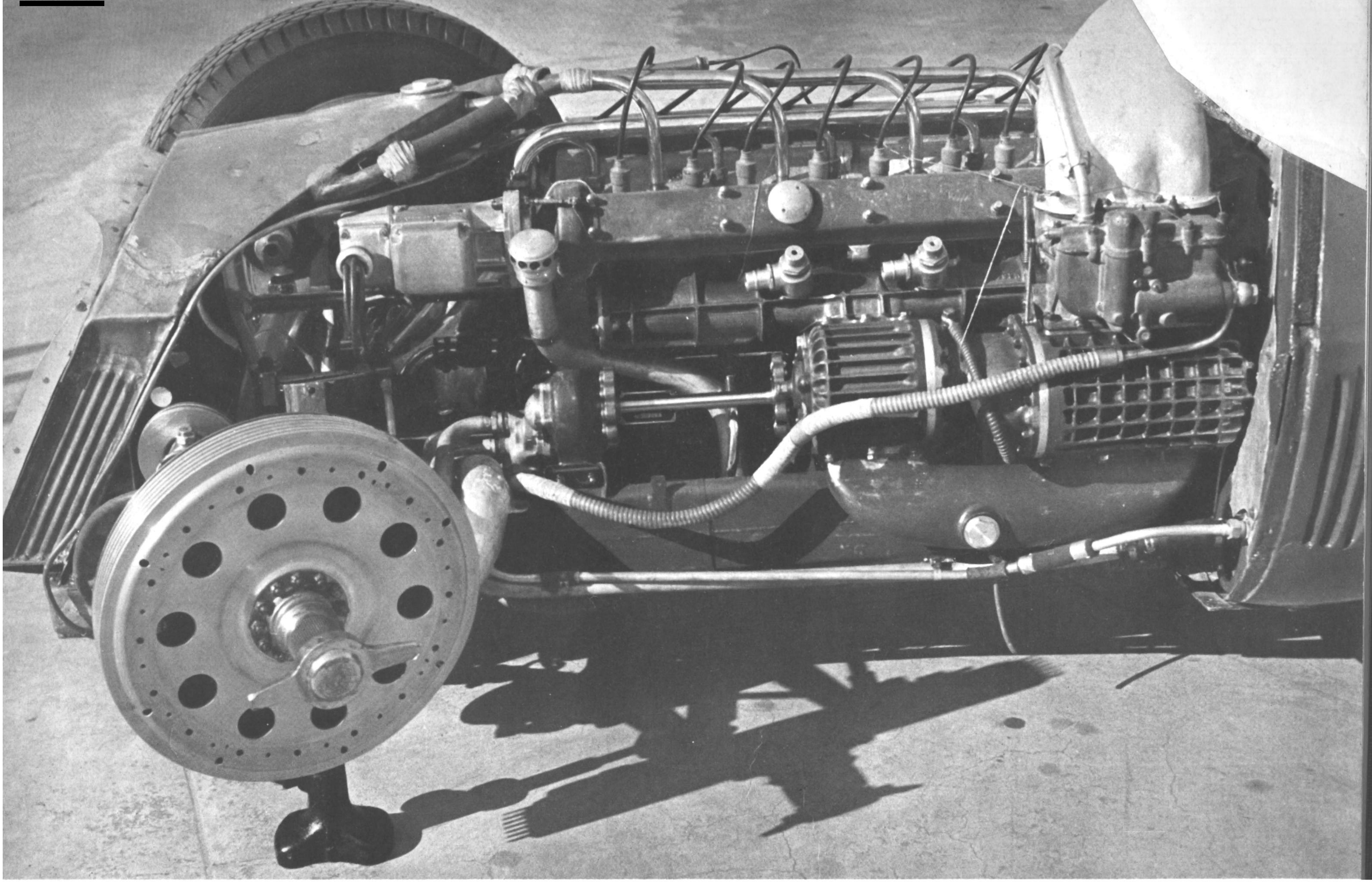
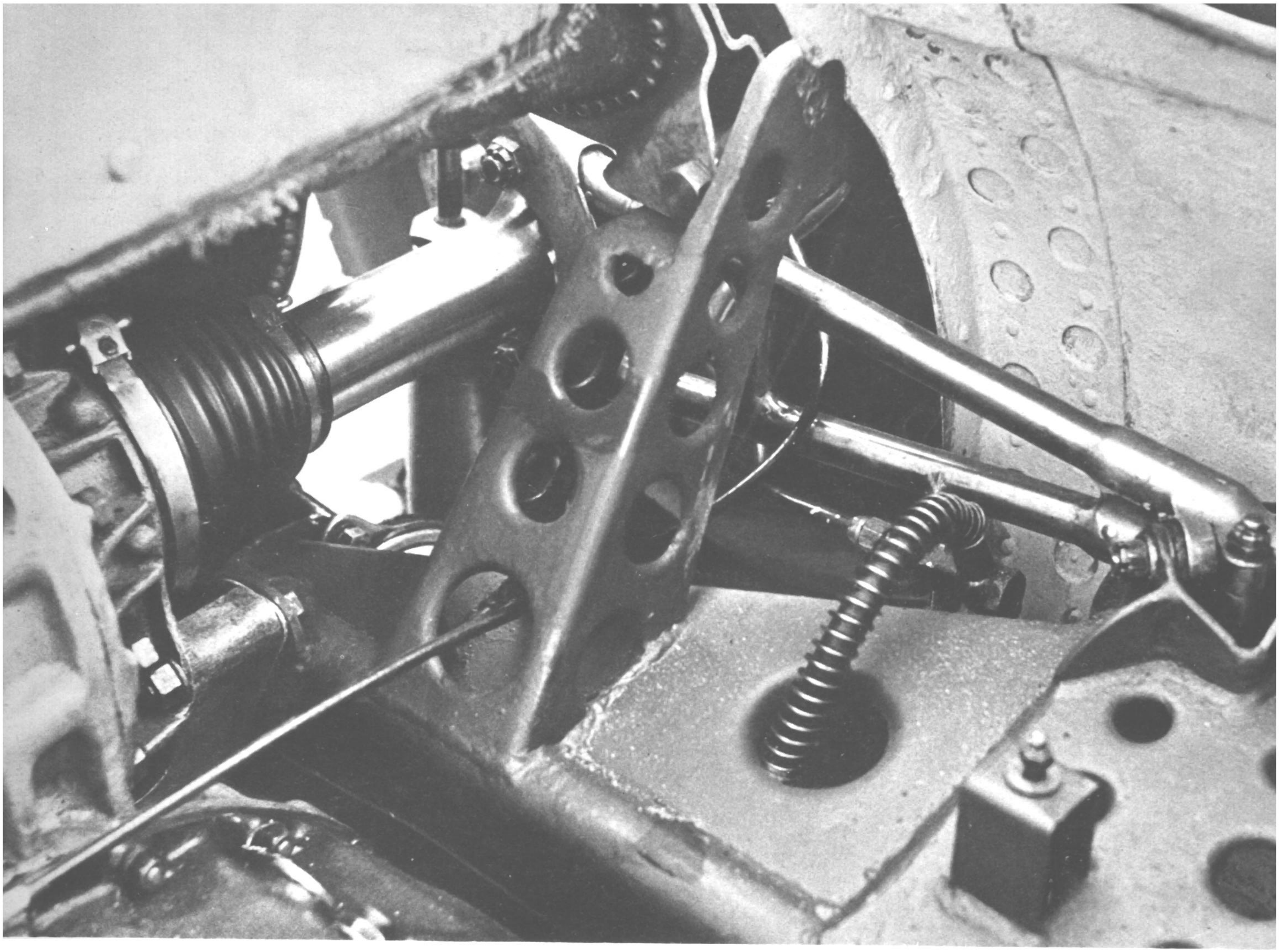


PLATE VIII

DOUBLED POWER- When originally bench tested, the Alfa Romeo engine (eight cylinders, 58 x 88 mm.), supercharged with a single Roots blower, gave 190 b.h.p. at 6,500 r.p.m. In final form as shown here, with triple.downdraught Weber carburetters drawing air from a vent on the scuttle with two-stage Roots blowing and high velocity water pumped directly into the face of the cylinder head, the engine gave a maximum of 404 b.h.p. at 10,500 r.p.m. with a normal rating of 385 b.h.p. at 9,500 r.p.m.



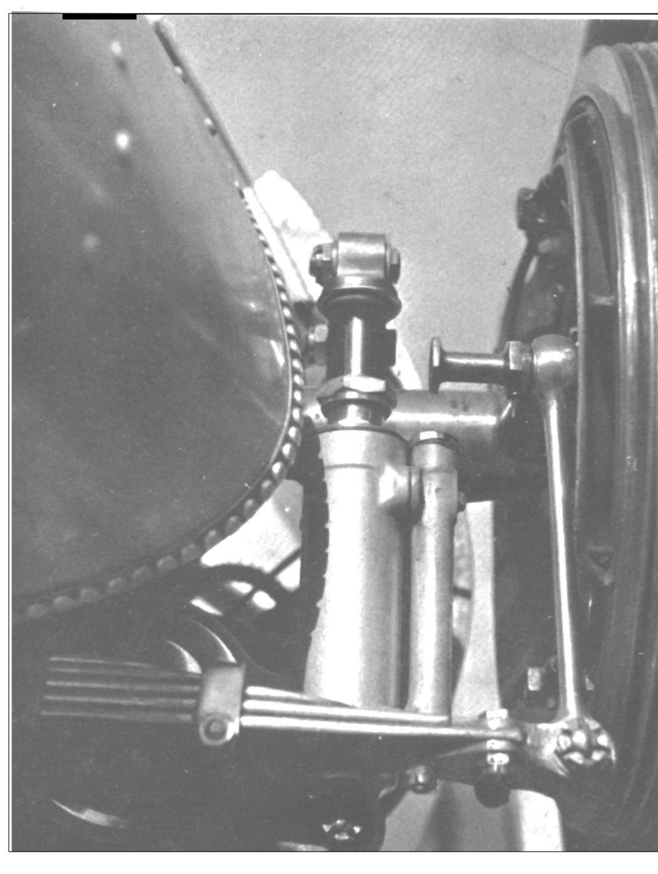


PLATE IX

SIMPLE SET-UP-The Formula I Alfa Romeo had trailing link front suspension with a single transverse leaf spring. At the back, as shown here, a simple swing axle layout was used (also in conjunction with a five-leaf transverse spring), the rear wheels being located by torque and radius arms. As shown, these were mounted on an inclined pivot giving toe-in on full bump in order to promote under-steer, and the axle tubes were given dihedral in normal laden condition for the same reason.

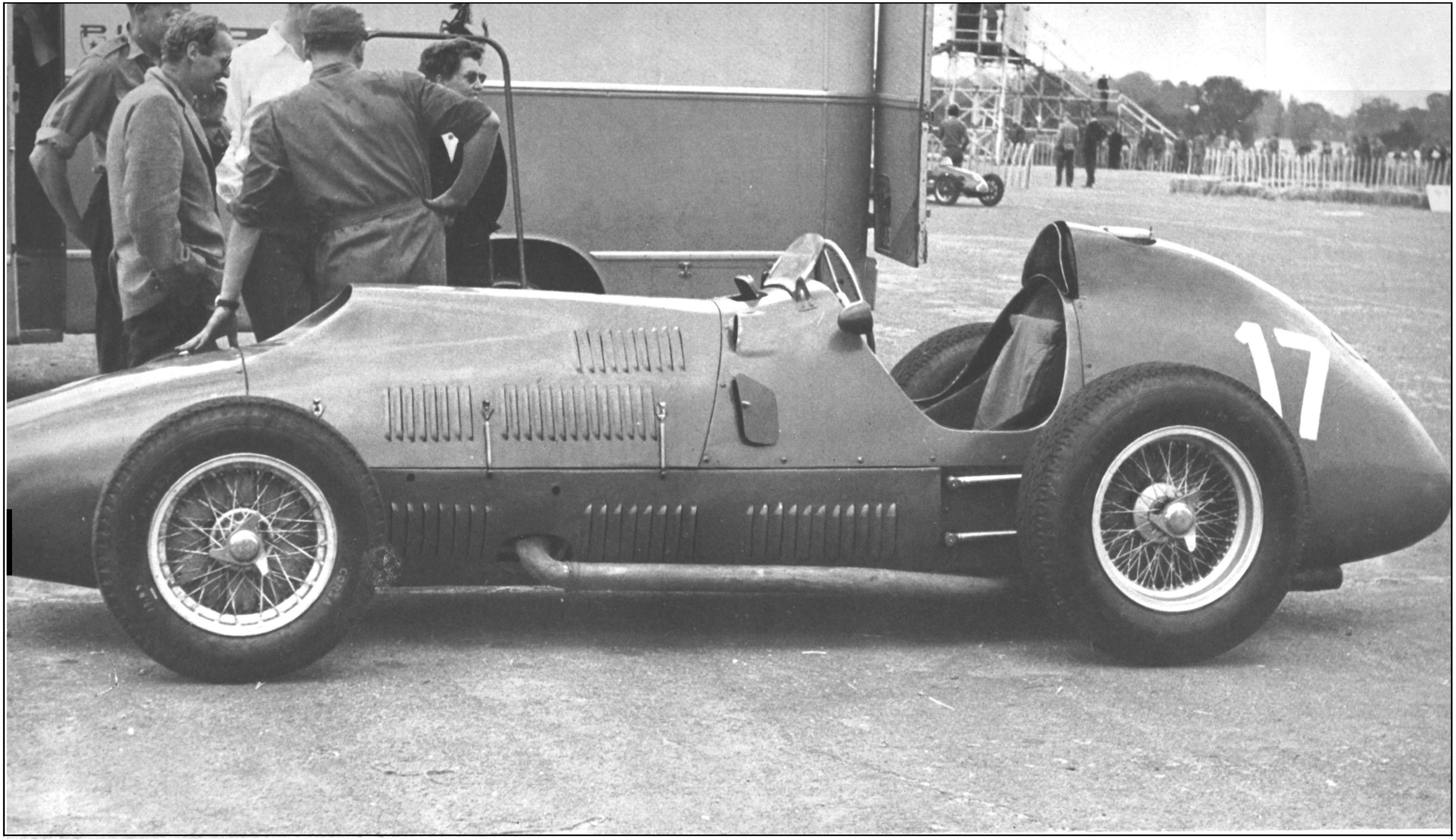


PLATE X

VICTORY BY INCHES -The twelve-cylinder (80 x 74.5 mm.) 4½-litre unsupercharged Ferrari was developed to give 380 h.h.p. for the Formula 1 racing of 1951, a figure subsequently raised to 430 h.h.p. These high outputs, derived.from more than 93 sq. in. of piston area, were combined with good low-speed torque and the car as shown here with ducted air flow and long-nosed cowl can claim to be the fastest road racing car built up to the end of 1953·

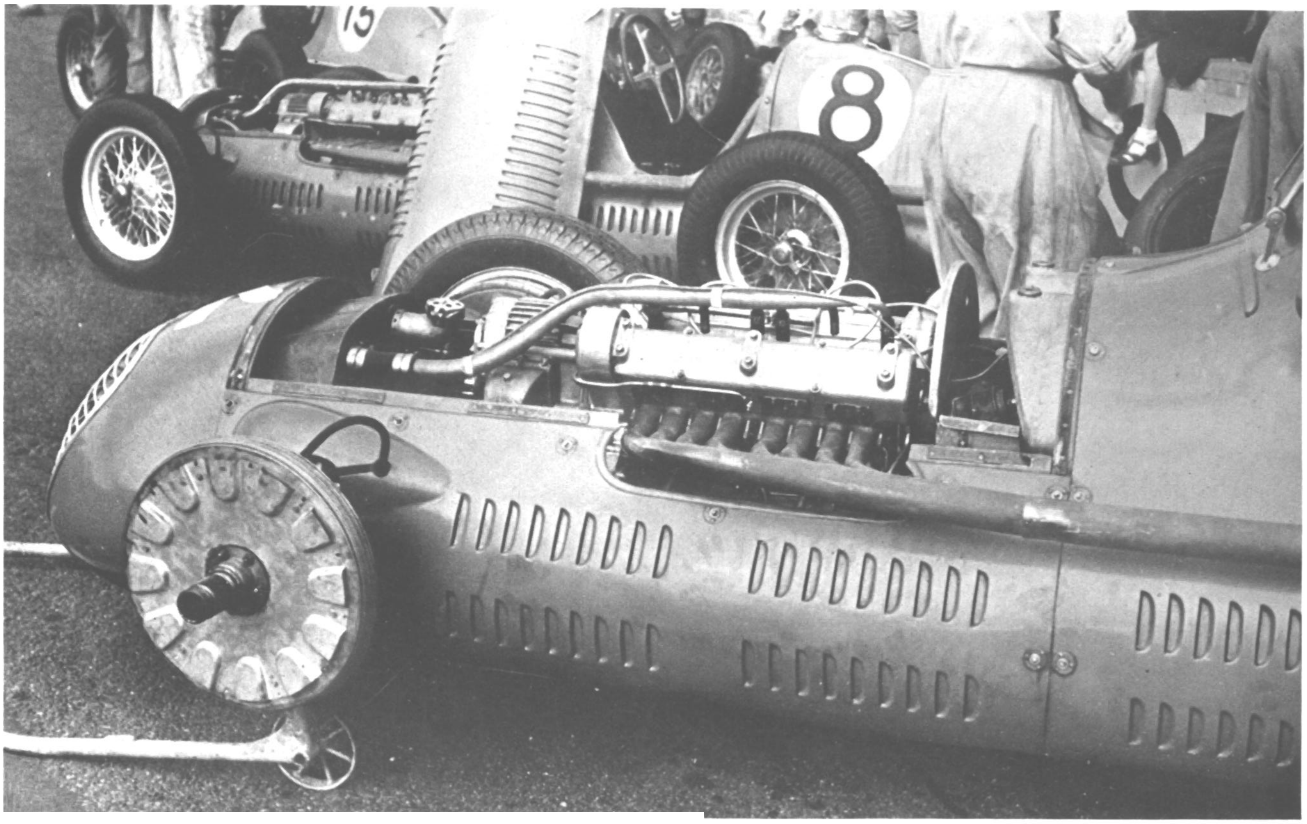
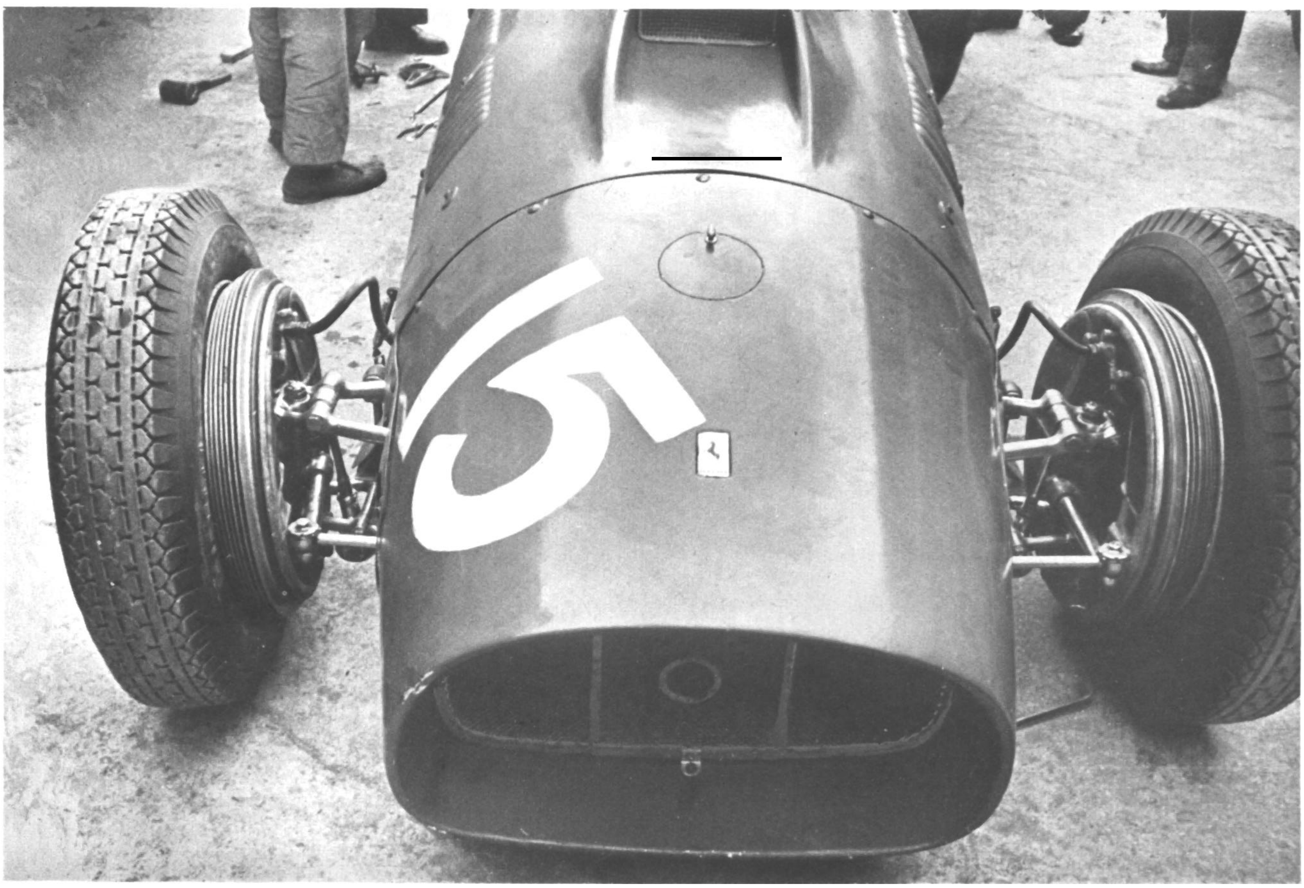


PLATE XI

STOPPING POWER-A mqjor contribution to improved circuit speeds in the post-war period has been greater stopping power obtained by improved friction lining materials and developments in brake drum design. Heat dissipation has been carefully studied, Maserati proneering ducted flow over the face of the drum (above, in 1949) and Ferrari the deeply inset drum with corresponding oflset between tyre centre and king-pin projection.



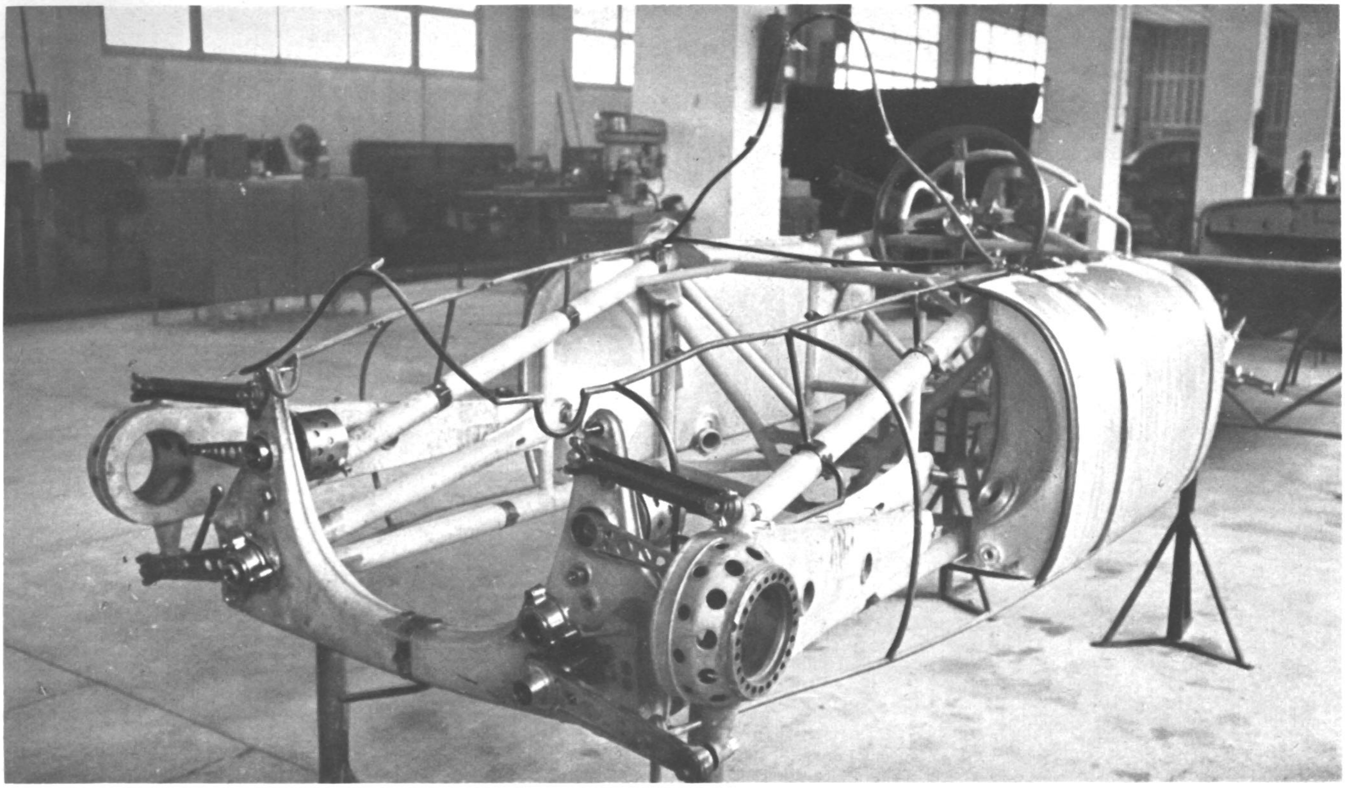
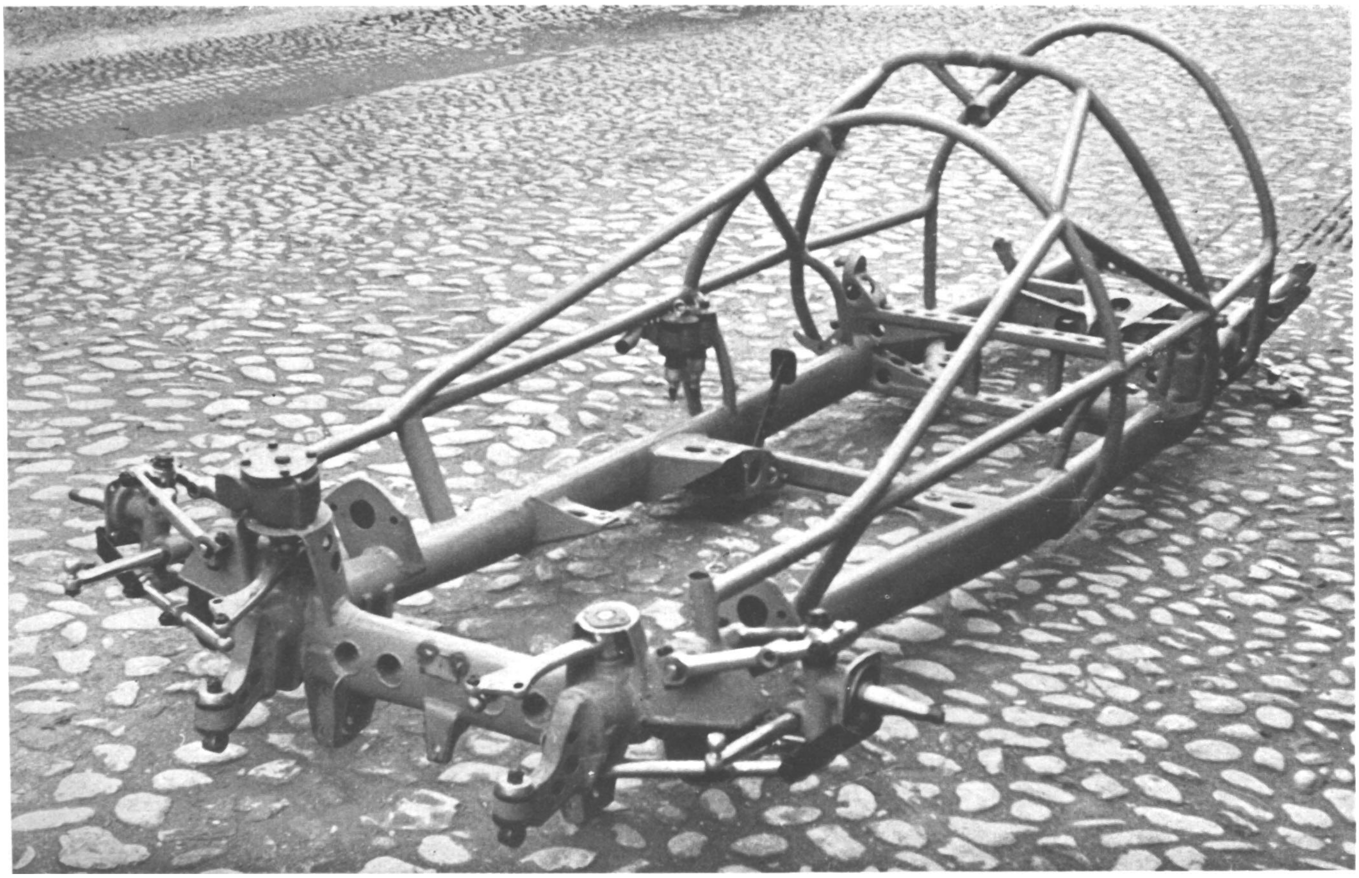
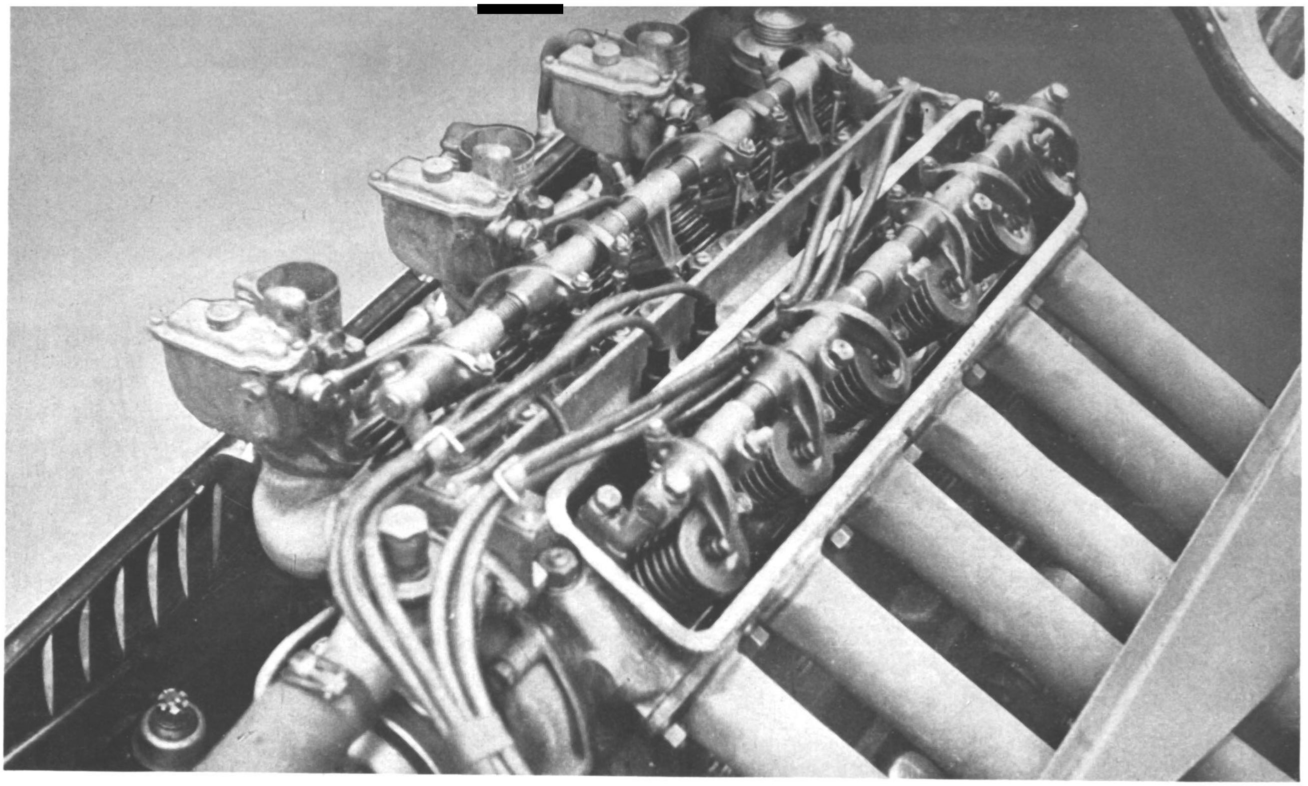


PLATE XII

INCREASING INERTIA -A notable feature of post-war racing car design has been the development of stiff lightweight frames of the " space " type using multiple tubes. Above is seen the frame (and rear suspension layout) of the rear-engined Porsche-designed Cisitalia and below the latest-type 4½-litre Ferrari (showing front suspension elements) in which a tubular superstructure reinforces the main frame members.





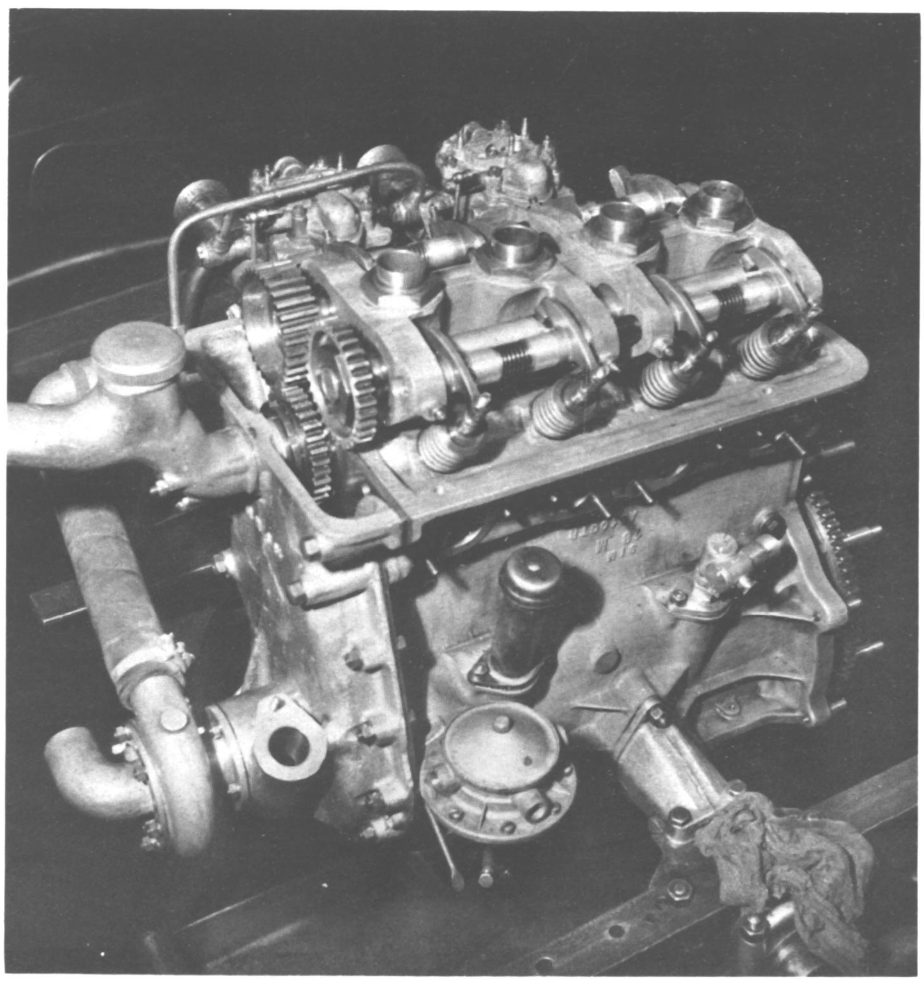


PLATE XIII

TWO PARTS OF GAUL-
With the death, in infancy, of the State-supported Arsenal C.T.A., French contribution to Formula I racing has depended upon Lago's Talbots and Gordini's Gordinis. These Italians chose alternative power units, Lago using six cylinders (93 x 110 mm.) to give 4½ litres unsupercharged with an output of about 270 b.h.p. Gordini used four cylinders (78 x 78 mm.) for a 1½-litre engine, used unsupercharged as shown for early Formula II races, and with a single-stage Roots blower for Formula I events.

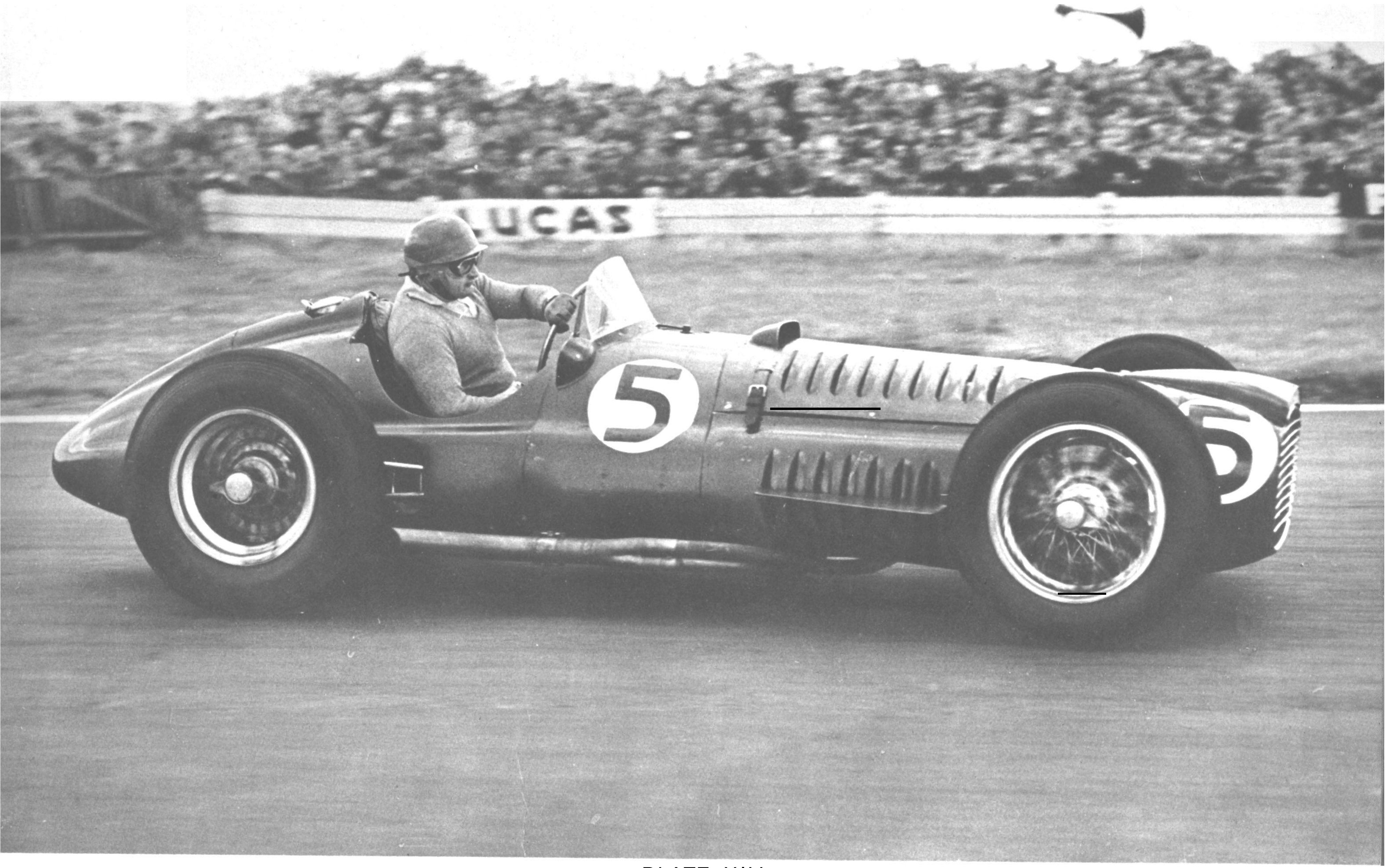


PLATE XIV

POWER WITHOUT GLORY- Developing far more power than any other Formula 1 car, the British B. R. M.s were beset by development and handling problems during the eflective life of Formula I. Subsequently, they combined over 500 b.h.p. with reasonable reliability and, with greater h.p./sq. ft. of frontal area than any car yet built, showed exceptional speed on fast circuits.

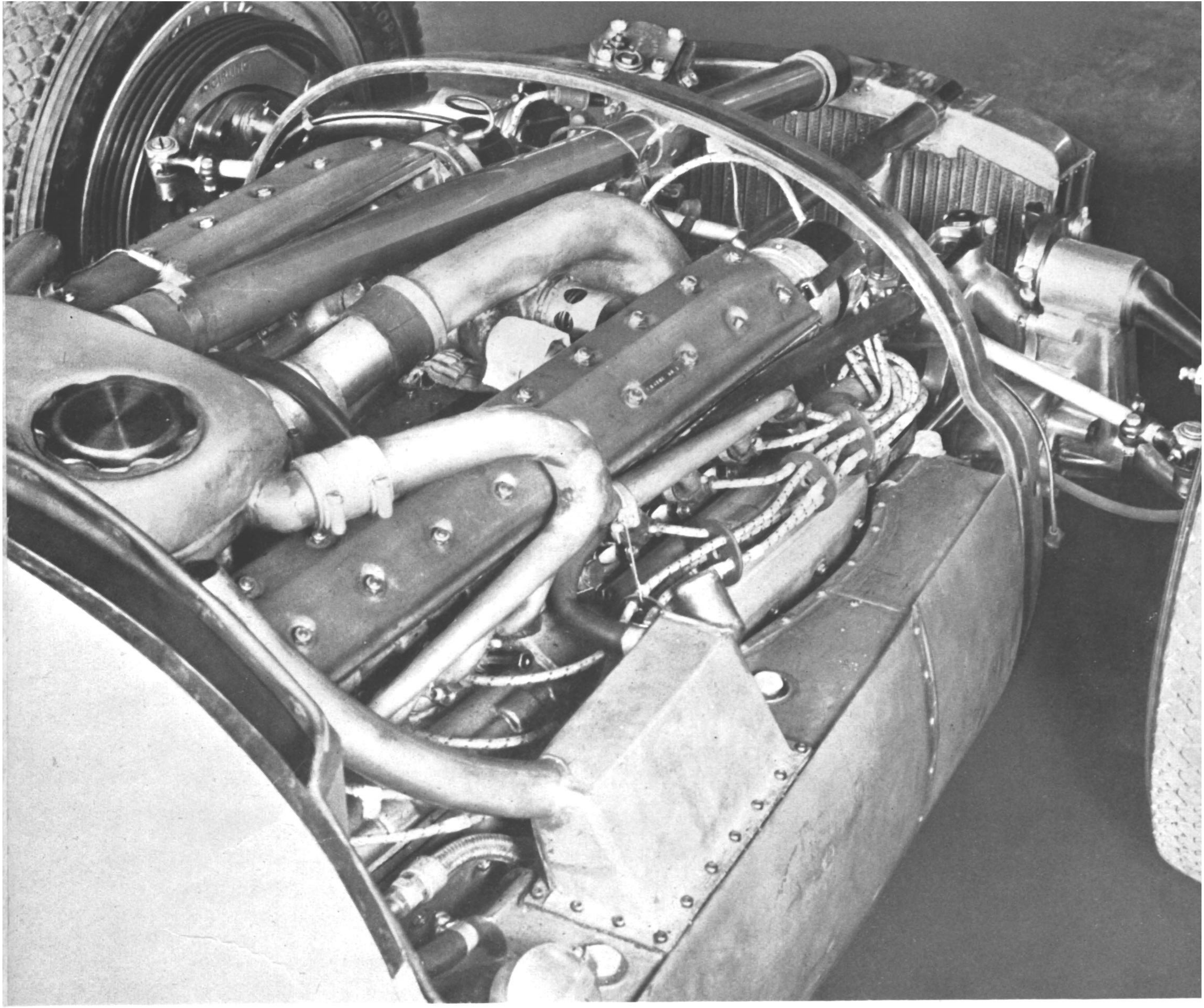


PLATE XV

LOGICAL EXTREMES - The sound premises that maximum h.p. would be obtained by an engine combining the greatest practical piston area and the highest possible boost led the B.R.M. designers to construct a V.16 (49.53 x 48.26 mm.) l½-litre engine designed to operate at over 10,000 r.p.m. with a boost pressure of up to 70 lb. per sq. in. from two-stage centrifugal blowers. The difficulties qf installing such an engine can in some measure be appreciated from this picture. It shows also the complexity of the ignition and water circulation systems.

PLATE XVI

EFFECTIVE SIMPLICITY - Of wholly orthodox design, the four-cylinder (90 x 78 mm.) 2-litre Formula II Ferrari cars achieved some extraordinary performances in the racing seasons of 1952 and 1953. These included the breaking of a number of absolute records of average speed for total race distances, the low power factors being offset by good handling and braking and the possibility of covering 500 km. without a pit stop.

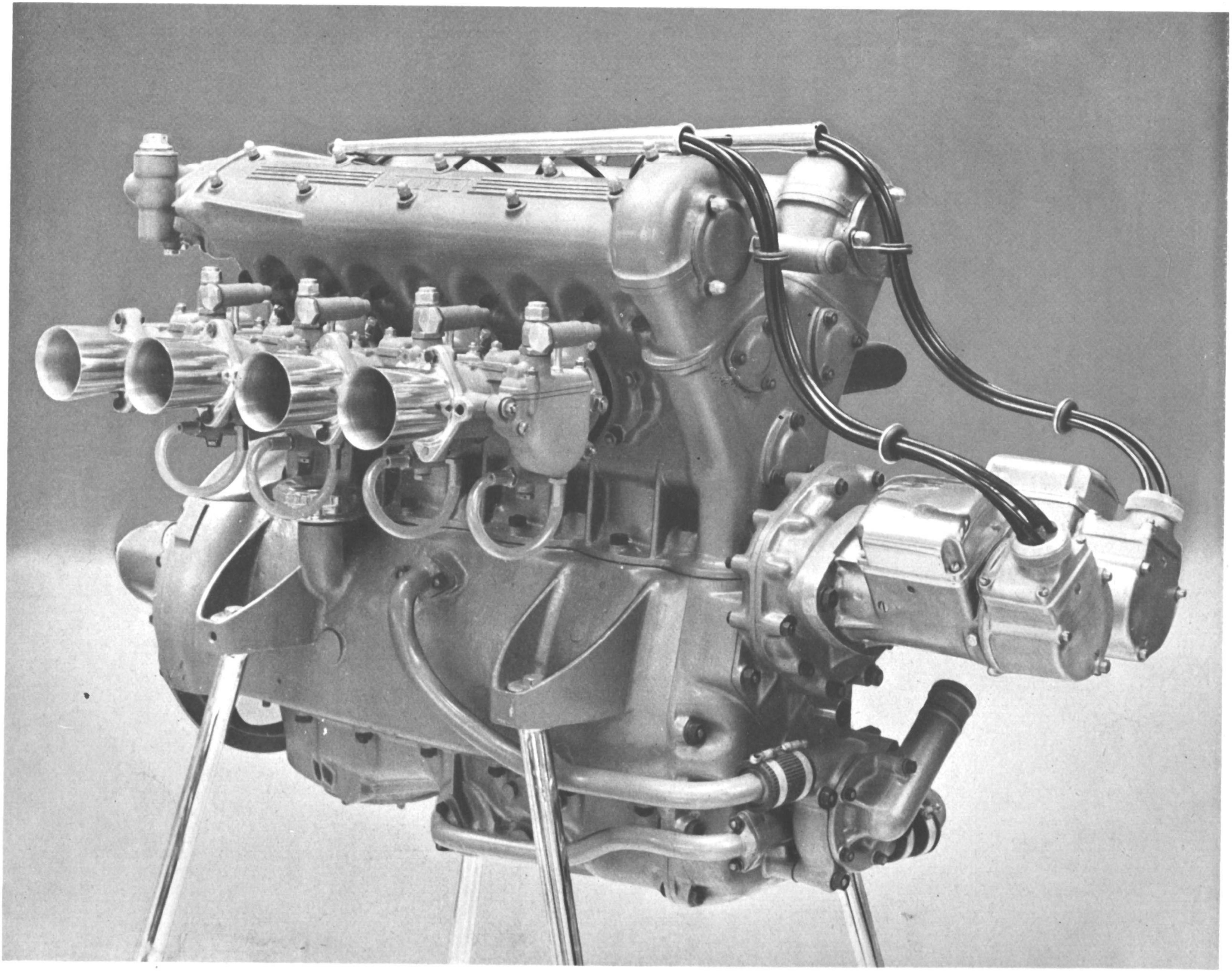


PLATE XVII

POWER FROM THE ATMOSPHERE - The simple four-cylinder Ferrari Formula II engine developed about 180 b.h.p. at 7,500 r.p.m. with the peak of the torque curve at 5,500 r.p.m. Each cylinder was fed by an individual Weber choke and jet assembly with lengthened intake pipes to give ram effect over the useful speed of the engine.

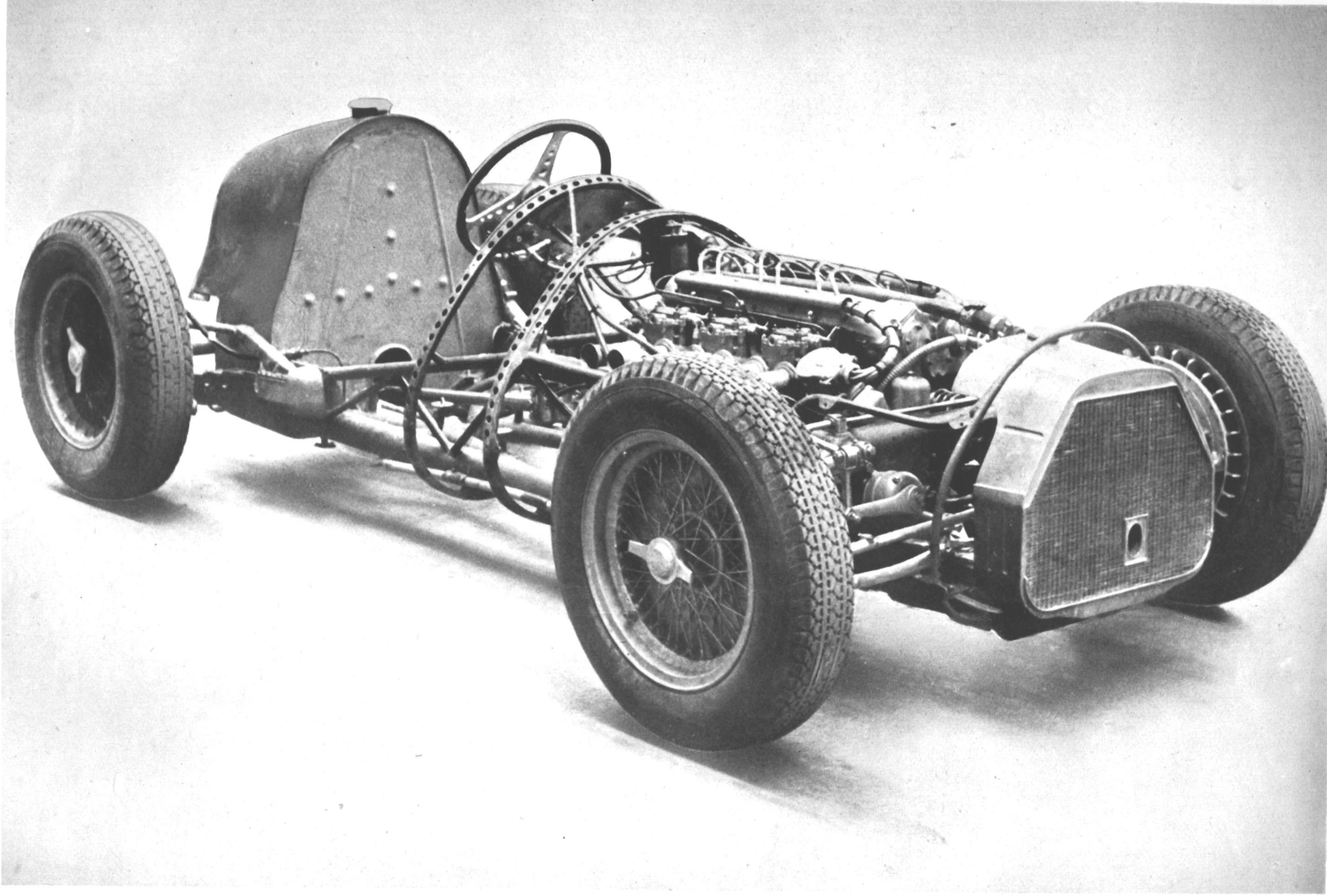


PLATE XVIII

FORMULA II CHALLENGER-The six-cylinder (75 x 75 mm.) Formula II Maserati was developed to give over 190 b.h.p. and, as shown here, the main frame members were stiffened by supplementary small-diameter tubes. In the Grandes Epreuves of 1952-3 this was the only car able to defeat the Ferrari.

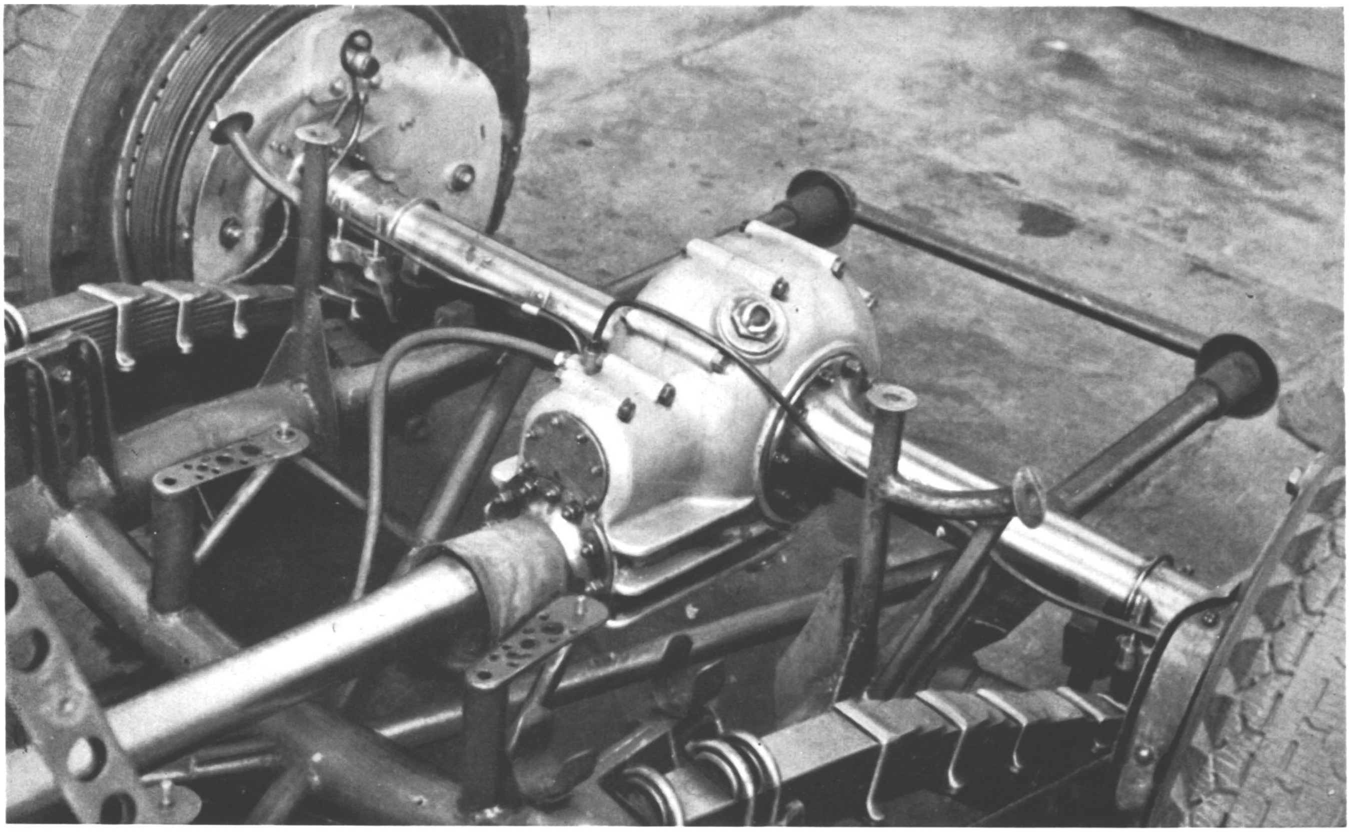
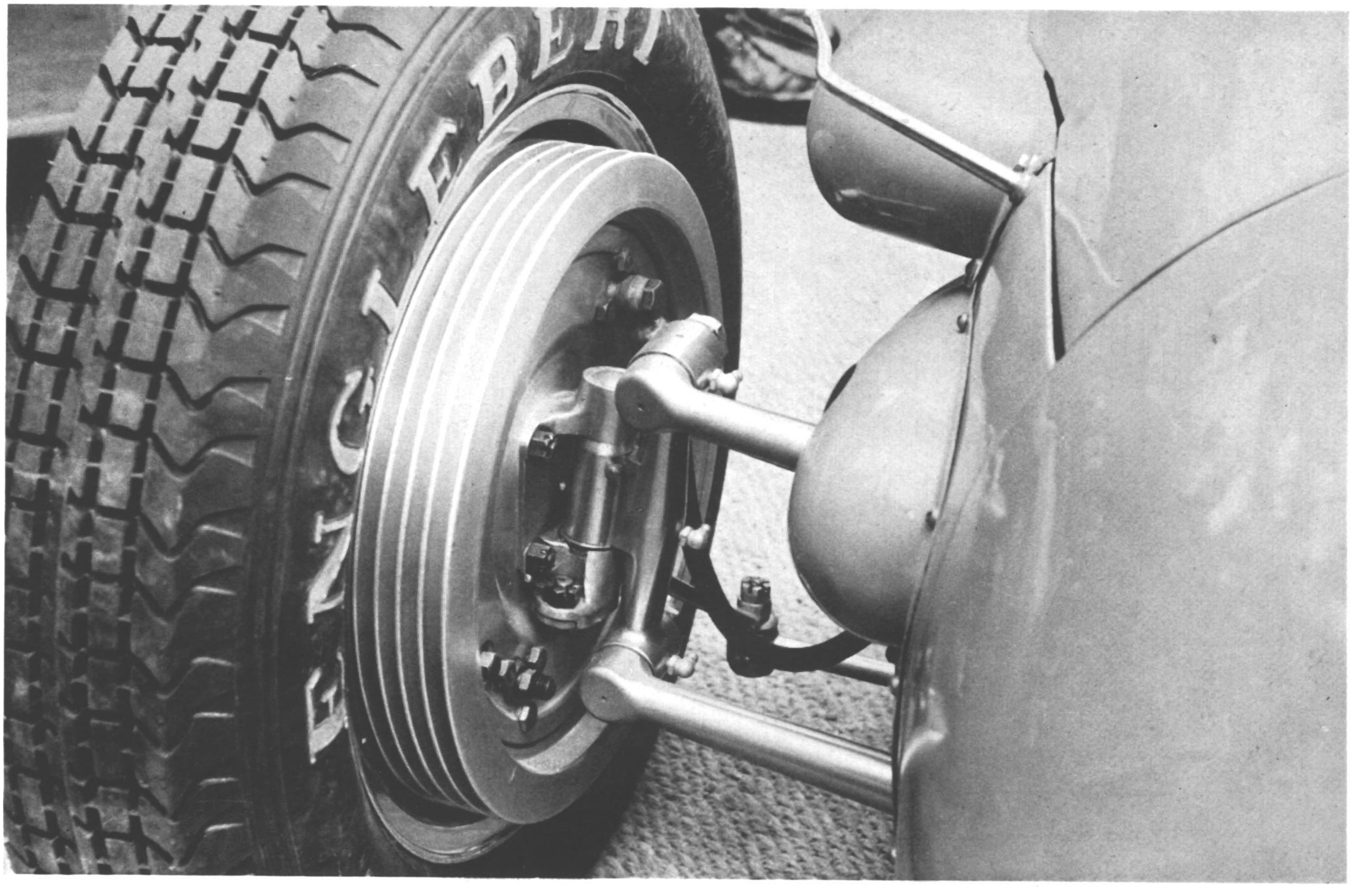


PLATE XIX

FORE AND AFT - Above can be seen a typical Maserati rear axle and rear suspension unit with double reduction gears, steel tubes attached to the light-alloy centre section and outwardly splayed quarter-elliptic springs.Below can be seen the single arm front suspension of the Formula II Gordini.



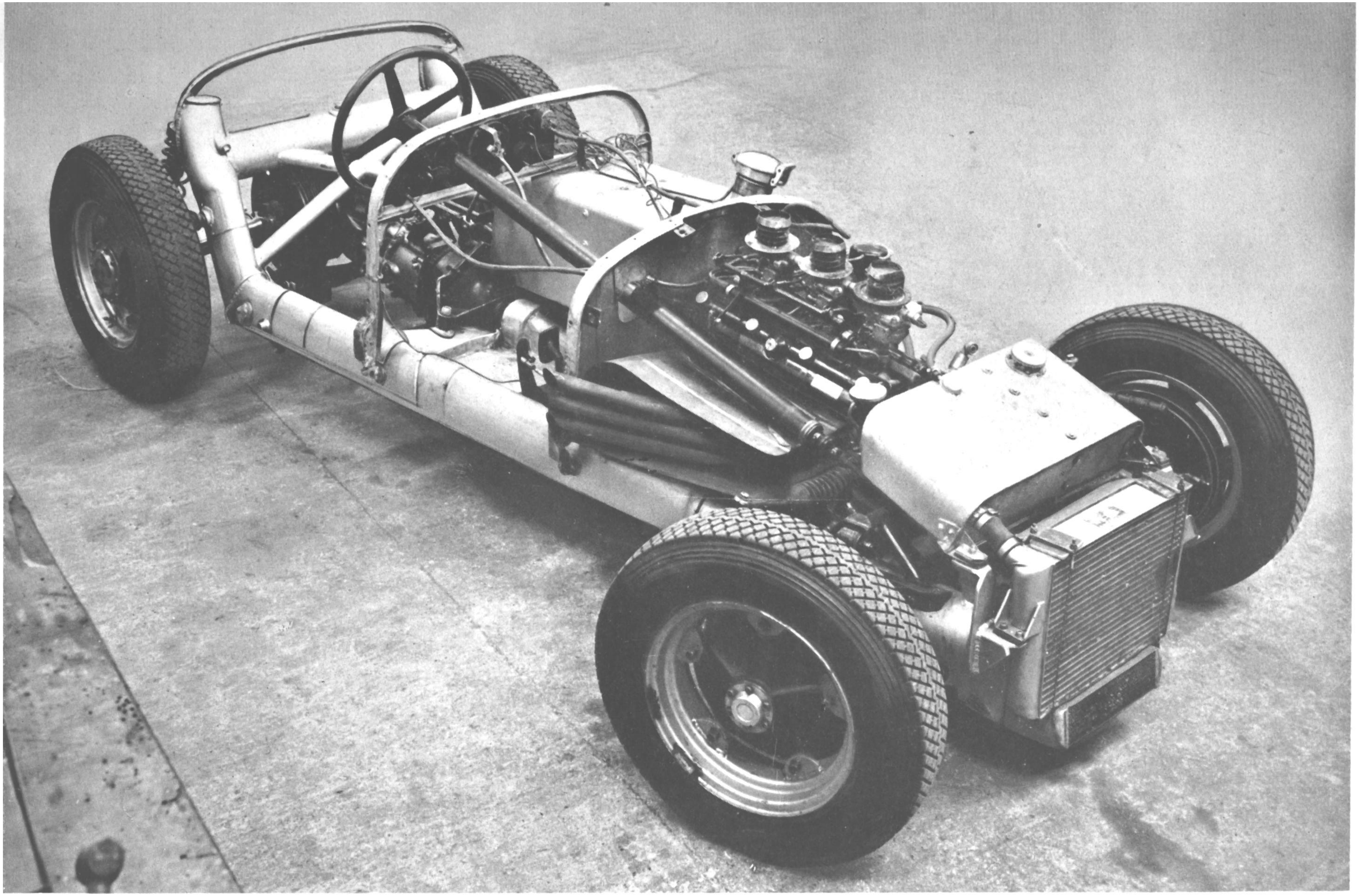


PLATE XX

LIGHTWEIGHT RESEARCH-The Formula II G Type E.R.A. used a chassis frame made from magnesium-zirconium alloy which resulted in a unique combination of simplicity, stiffness and light weight.Other interesting features cf this car included a de Dion rear axle with low roll centre, face-cooled brakes and ducted air flow through the radiator.

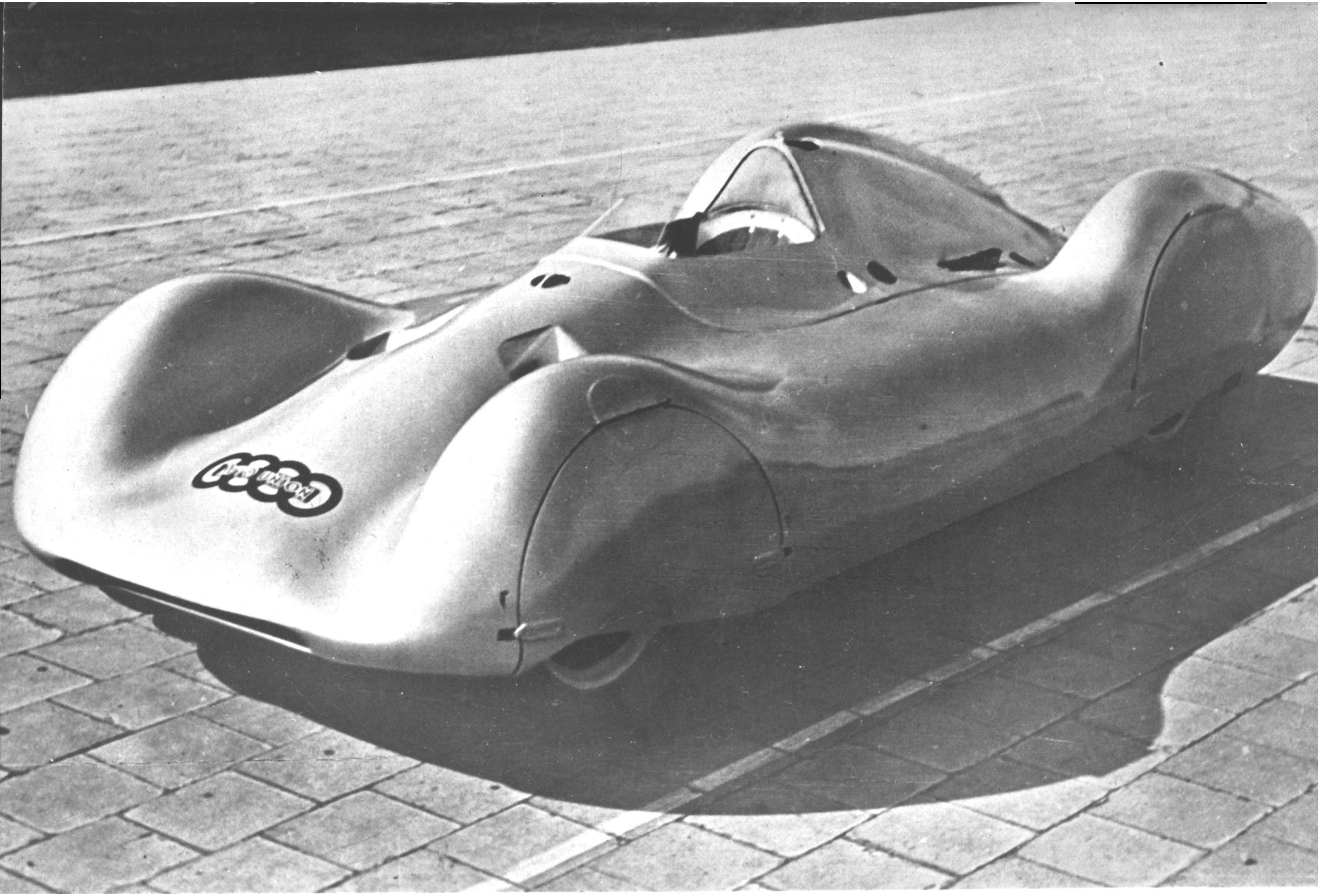


PLATE XXI

LOW DRAG EXPERIMENT - In 1938 Auto Union built two 3-litre rear-engined cars with enveloping bodies.. These proved unstable and were not used for subsequent racing but may nevertheless be considered prophetic of the shape of cars to come.

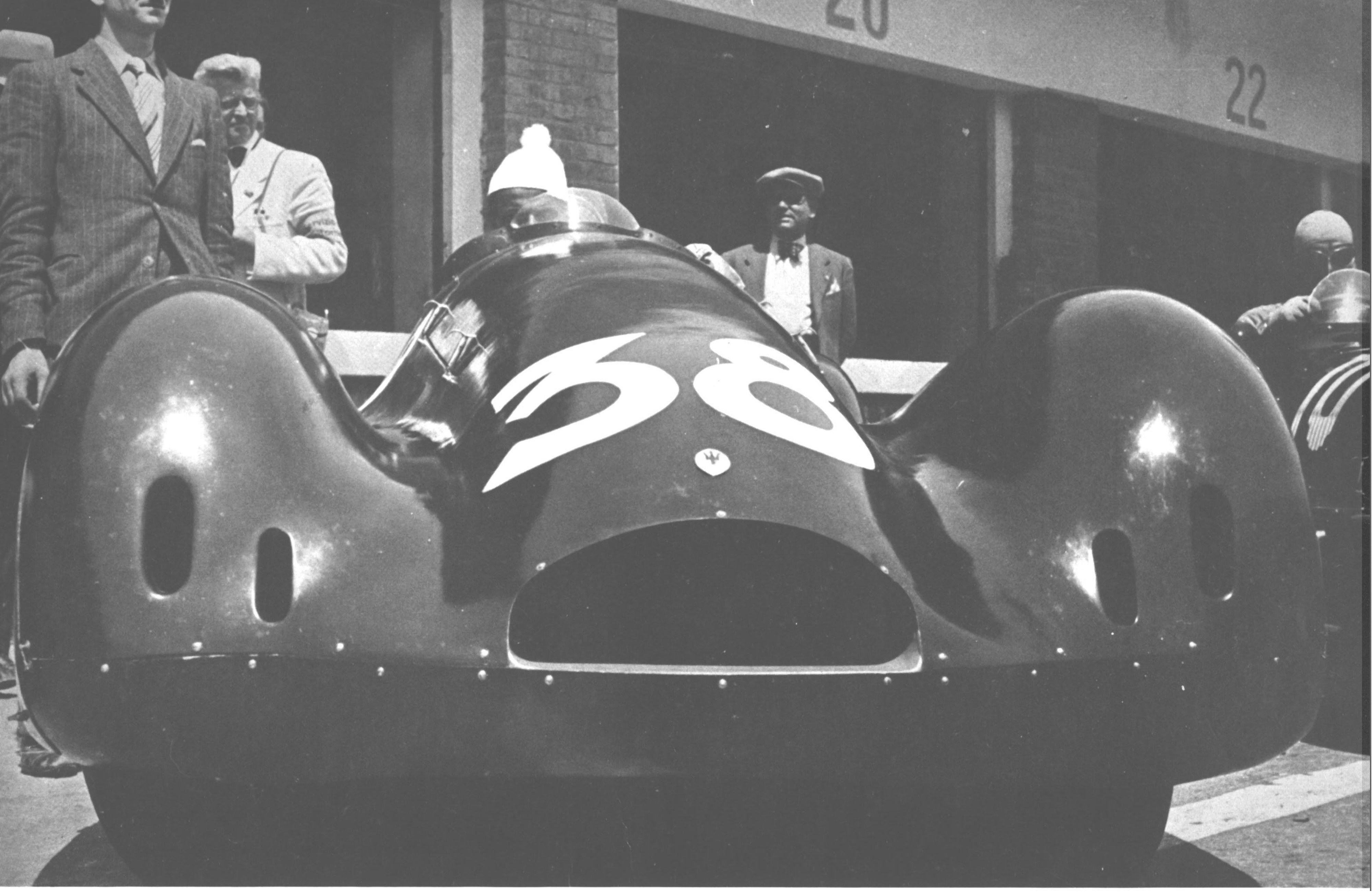


PLATE XXII

SUCCESSFUL STREAMLINER - This cowled-in Maserati appeared at Tripoli for the l½-litre race of 1939, and although retiring with engine trouble it lapped at 134 m.p.h. in practice, being 0.6 secs. faster than cars with 20% more power. It has foreshadowed the day when the classic shape of racing car developed in the first fifty years of the twentieth century will be seen no more on the racing circuits of the world.

CHAPTER SIX

How Fast Did They Go?

THE opening chapters of this volume, and the whole of Volume I, have been devoted to an objective description of Grand Prix racing and of the principal designs of Grand Prix cars in the period 1906-53. A subsequent section will deal with the design of the Grand Prix car from a different viewpoint ; in it the writer will analyse the various qualities which make up the successful racing car, demonstrate how they have been synthesized over a period of years, and indulge in a measure of subjective comment and criticism. Some account will also be rendered of how external factors, such as the incentives which have impelled manufacturers to enter Grand Prix racing, the finance which they have had at their disposal, the roads over which the cars have had to run and, above all, the international regulations with which they have had to comply, have each and severally influenced the designers in the decisions they have made.

Before proceeding to this new section it may be appropriate to consider, again objectively, the relative speeds of the racing cars which have already come under review. The maximum speeds of the chosen examples have been set out in their specifications, but on road racing cars it is speed over a circuit which is all important. It might seem at first that it would be almost impossible to compare the average speed potentiality of, say, a 1928 car with one built twenty years earlier or twenty years later. As will be shown in a later chapter there is, in fact, a close relationship between maximum speed and circuit speed on cars of similar size, weight and road-holding characteristics. This relationship is that, broadly speaking, circuit speeds will vary as the square root of maximum speeds or equally as the sixth root of h.p./sq. ft. of frontal area.

In the example above cited, there will be wide differences in size, power and road-worthiness, but these variations notwithstanding, we can profitably examine the lap speeds set out in the tables of Volume I, and in the foregoing chapters of Volume II, with a view to comparing similar cars on differing courses, or alternatively differing cars on similar courses. It is possible to study the case of the similar car on differing courses at a very early stage in motor racing, in the years preceding Grand Prix racing proper in fact.

The 13.6-litre Gobron-Brillé, which ran in the first Grand Prix of all, in 1906, was unchanged, dimensionally or in design, since 1903, in which year this model had been first constructed. A study of the lap times in the 1903 Circuit des Ardennes shows that the Gobron, driven by the professionals Duray and Rigolly, was some 7 per cent slower on a lap than the 70 h.p. Mors driven by the amateur Vanderbilt. We can, therefore, say that in this year the Gobron, as a car, was perhaps as much as 10 per cent slower than the winner of the 1903 Paris-Bordeaux, which was the last great town-to-town race.

In 1904, the Gobron was in competition with the 100 h.p. Mors, in the French eliminating trials for the Gordon Bennett Cup, which took place on the Circuit de l'Argonne, and here it was 6 per cent slower. In 1905 we see it 9 per cent slower than

the 13-litre Renault which ran in the French eliminating trials for the Gordon Bennett Cup, and finally, in 1906, it is 10 per cent slower than the similar 13-litre Renault which won the first Grand Prix de 1'A.C.F.

To sum up, if the speed of the Gobron had remained unchanged from 1903 to 1906, we could deduce that the 1903 Mors was very nearly as fast as the 1906 Renault but in the nature of things, the speed of the Gobron-Brillé would increase from year to year. If the difference in five years amounted to, say, 5 per cent, then we can safely say that the 1903 Gobron-Brillé was 15 per cent slower on a circuit than the 1906 Grand Prix winner. As we know already that it was between 7 per cent and 10 per cent slower than the Mors which won the Paris-Bordeaux, it follows that the Mors, in turn, was between 5 per cent and 8½ per cent slower than the 1906 car. We might reasonably take 6 per cent as a fair estimate ; as the fastest Le Mans lap made by the Renault was 72.1 m.p.h. we might anticipate that the Mors would lap at a little over 69 m.p.h., and as it averaged 65.3 m.p.h. over the 342 miles between Paris and Madrid, it was obviously capable of so doing. It would thus seem that there was relatively slow progress in the development of the racing car, between 1903 and 1906, an example of this being that the 1904 100 h.p. Mors was timed at 88 m.p.h. over a flying kilometre on the Argonne course and the 1906 Renault at 92 m.p.h. at Le Mans.

Having now illustrated how to establish lap speed indices (which without undue egoism may perhaps be called " Py factors "), by going backwards in time relative to the first Grand Prix, let us see how the system can be applied from 1906 onwards. We can do this with an interesting equation which takes into account, first, two similar cars and, secondly, two identical circuits.

Owing to the fortunate coincidence that the Renault Co. ran the same type car in 1907 on the Dieppe circuit as they had run at Le Mans the previous year, coupled with the fact that the 1908 race was run over the same roads as those employed in 1907, we have a chain of circumstances which enable us directly to compare the performances of all the Grand Prix cars running in these three years. Hence, by the study of lap times we can award a lap speed index for the cars running in these races and by making a corresponding analysis of subsequent events we can, with a very fair degree of accuracy, relate the average speed capabilities of all racing cars built from the earliest times.

If appropriately we give an average lap speed index of 100 to the 1906 winner which had a timed maximum speed of 92.2 m.p.h., we then have corresponding indices in the 1906 race of 101.4 for the Richard-Brasier (which made the fastest lap) and 98.6 for the Fiat which was runner-up in the race as a whole.

If we now carry forward this lap speed index figure of 100 for the Renault performance on to the Dieppe circuit of 1907 we shall find that the winning Fiat has a lap speed index of 102, that the De Dietrich which made the fastest lap has an index of 103.2, whereas the Richard-Brasier which was faster than the Renault in the previous year is now slower, the best car of this make having a speed equivalent to index of 97.5.

It will be observed that, using the 1906-7 Renault as a datum, the lap speed of the fastest car rose by 1.7 per cent in one year, but substantially greater gains were made in the ensuing 12 months. On the identical Dieppe circuit of 1908 the relative performances of the principal makes were :

Mercedes (record lap) with index of	107.5
Richard-Brasier	106.8
Renault	105.6
Fiat	105.5
Clement-Bayard	104.6

It is possible to check these relations based on fastest lap speeds by reference to maximum speeds timed over a kilometre for Faroux of *l'Auto.* These were :

Clement-Bayard 104.8 m.p.h. ; Mercedes 104 m.p.h. ; Benz, de Dietrich, Fiat and Richard-Brasier 101.3 m.p.h. ; Renault 99 m.p.h. ; Itala 97.8 m.p.h. ; and Panhard 90.5 m.p.h.

These figures show that the 1908 Renault was 7 per cent faster " flat out " than the 1906-7 model, and the winning Mercedes 13 per cent faster.

We may also analyse performance in these early years of motor racing by referring to speed trials and hill climbs. Of the latter the Mont Ventoux event in France is particularly useful, since the course is 13 miles 750 yards long, and it was used for racing cars between 1902 and 1934. The times from 1903-5, that is the Gordon Bennett era, and from 1907-9 were as follows :

TIMES AT MONT VENTOUX 1903-9

Year	*Driver*	*Car*	*Time*
1903	Danzeau	Richard-Brasier	25 min. 25 sec.
1905	C. Cagno	Fiat	19 min. 30 sec.
1907	H. Rougier	De Dietrich	19 min. 30.4 sec.
1908	P. Bablot	Richard-Brasier	19 min. 8.8 sec.
1909	„	„ „	18 min. 41 sec.

These results support the thesis that there was little gain in speed between 1905 and 1907, but that the 1908 cars were much superior. This view is confirmed again by reference to the times made by Gordon Bennett or Grand Prix type cars in various speed trials. Here we have evidence for both standing start and flying start speeds as follows :

SPEEDS OVER STANDING MILE 1903-9

Year	*Course*	*Car*	*Driver*	*Speed*
1903	Nice	60 Mercedes	H. Braun	56.5 m.p.h.
1904	Nice	60 Mercedes	W. Werner	62.3 m.p.h.
1905	Brighton	120 Mercedes	J. E. Hutton	74.4 m.p.h.
1909	Indianapolis, U.S.A.	1908 G.P. Benz	B. Oldfield	83.0 m.p.h.

STANDING KILOMETRE SPEEDS

1906	Le Mans	1906 G.P. Itala	Fabry	52.4 m.p.h.
1909	Tervueren	1908 G.P. Mercedes	T. Pilette	67.4 m.p.h.

SPEEDS FOR FLYING MILE OR KILOMETRE

1902	Deauville	Mors	Gabriel	84.7 m.p.h.
1903	Nice	G.B. Mercedes 60	H. Braun	72.7 m.p.h.
1904	G.B. Trials	Richard-Brasier	L. Thery	74.5 m.p.h.
1905	Ostend	G.B. Darracq	L. Wagner	95.6 m.p.h.
1909	Ostend	1908 G.P. Mercedes	C. Jenatzy	112.0 m.p.h.

Accepting the postulate that lap speed varies with the square root of maximum speeds, the increase in average speed of the 1908 Mercedes over the 1906-7 Renault should be 5.7 per cent. This agrees with the results obtained in Grand Prix racing to within an error of only 0.2 per cent. Moreover, on the basis that maximum speed should vary as the cube root of the engine power the output of 90 b.h.p. for the Renault, as claimed by the makers, leads to an assumption of 128 b.h.p. for the Mercedes for which the claimed power was 135 b.h.p.

The 1912 Peugeot which won the next Grand Prix organised officially by the Automobile Club de France was a car exhibiting great technical progress but had an engine substantially smaller than the 1908 Grand Prix winner, and offered no great increase in basic performance factors.

The qualification is an important one, for whilst the car ran over the identical circuit which had been used in 1908 it was required to do so during two days for a total of 956 miles, whereas the earlier event had been confined to one day with a total mileage of 479. It is therefore scarcely surprising that the final winning speed was 68.45 as compared with 69 m.p.h. ; the best lap 75 m.p.h., as compared with the 1908 Mercedes 78.5 ; and that the Peugeot's timed maximum during the race of 99.86 m.p.h. was lower than the 104 m.p.h. recorded four years earlier by the Mercedes.

There is another side to this picture. During practice Peugeot was timed to beat the 1908 lap record and over the first ten laps of the Dieppe course the Peugeot was 4.5 per cent faster than the winning 1908 Mercedes. It also climbed the Mont Ventoux hill in 5 per cent less time than the 1908 Richard-Brasier (Index 106.8). If we were to take these figures on their full face value we should give an average lap speed index to the Peugeot of 107.5 plus 4.5 = 112 if using the Mercedes as a datum, or 106.8 plus 5 = 111.8 taking the Richard-Brasier as a guide. Yet it seems unlikely that the Peugeot was capable of lapping the Dieppe circuit at as much as 82 m.p.h., and it was certainly running in a very stripped and highly tuned condition in its hill climb appearance. A balance struck between the two index figures given by the foregoing calculations and the 102.5 representing the actual lap speed during the race gives us a fair assessment for the average speed index for the 1912 Grand Prix Peugeot of 108.8.

The 1913 Delage, in turn, when running on the Le Mans circuit used for the

Sarthe Grand Prix had a lap speed 5 m.p.h. faster than the 1912 Peugeot on the same course the previous year. If, therefore, we consider the Peugeot and the Delage cars of 1913 to be roughly equal in speed we must conclude that both could average some 6 per cent faster than the Dieppe and Le Mans speeds of the 1912 Peugeot. There is an additional piece of evidence that the 1913 Peugeot was 1 per cent faster than the 1912 model at the Mont Ventoux hill climb, the driver being Georges Boillot in both years.

We have, however, just concluded on quite reasonable evidence that the realised speed of the 1912 Peugeot was at least 6 per cent less than the potential owing to the big required mileage of the French Grand Prix and the absence of competition at Le Mans. It is therefore probably sound to conclude that the 1913 5.6-litre Peugeot was only slightly faster than the 1912 7.6-litre car and that it had an average speed index of 109.5 as compared with the original Grand Prix winner.

When we come to analyse the speed capabilities of the 1914 cars we are confronted with the fact that the Lyons course cannot be calibrated against previous circuits and that by the almost immediate outbreak of war thereafter subsequent data concerning the cars is meagre. Certain evidence from the U.S.A. remains.

In 1915 Dario Resta used a 1913 5.6-litre Peugeot for the opening event of the year, but his subsequent change to the 1914 type was in any case involuntary as the older model was outside the 300 cu. in. (4.9-litre) limit imposed for 1915. In the 1915 Indianapolis Race, de Palma, driving the 1914 Mercedes car, does not appear to have attempted any exceptional speeds in practice, but he covered the first 300 miles at an average speed of 90.3 m.p.h., whereas the 1913 Delage car averaged only 83 m.p.h. over the same distance in 1914. Lap speeds of over 109 m.p.h. were also realised by the Peugeot on a variety of board tracks in the U.S.A. In a detailed account of the 1914 Mercedes racing cars, issued by the manufacturers in 1915, they state that initial tests showed a speed of 102.5 m.p.h., which was later raised to 120 m.p.h. This last would represent an increase of 30 per cent over the 1906 cars in maximum speed and an expectancy of a 15 per cent gain in overall circuit speed, i.e., an average index of 114. Unfortunately we can make no direct check on the accuracy of this estimate, except on the track of Indianapolis, as this was the only course used by the winning designs of 1908, ‘12, ‘13 and ‘14.

Taking our previously established average speed index for the 1908 Mercedes at 105.5 the Indianapolis performances gives us an index of 112 for the 1914 car which we can accept, as it gives an inferred, and quite reasonable, maximum speed of 116 m.p.h.

The 1919 4.9-litre Ballot, which was the fastest car built immediately after the break caused by the war-time years, had an engine only 10 per cent larger than the 1914 Grand Prix winner but eight cylinders instead of four, thus permitting higher r.p.m. within a given limit of piston speed.

The question of how the Indianapolis Ballot can be related to previous and subsequent Grand Prix cars is, strictly, irrelevant, for it never ran in an internationally recognised Grand Prix. Indianapolis and Brooklands tracks provide the sole criteria of its performance, with lap speeds of 105.5 m.p.h. and 112.17 m.p.h. respectively. Additionally, at Brooklands, the car set up the following internationally recognised records :

Standing kilometre	65.14 m.p.h.
Standing mile	75.44 m.p.h.

Inferred average kilometre to mile	101.5 m.p.h.
Flying kilometre	118.36 m.p.h.

(26/10/25) A.I. Nos. 7, 8 and 9.

Making due allowance for the effect of a riding mechanic we can put the estimated road speed at 115 m.p.h. maximum and applying the square root law in comparison with the first Grand Prix winner we are given an average index of 113.5. From this stage forward, however, it is imperative to take account of the use of front brakes which, although not used by the Ballot on the above-mentioned tracks, were fitted when it took part in the Targa Florio race of 1919. If we give a bonus of 5 per cent to the added circuit speed on account of this development we derive an index of 118.5.

It is unfortunate that, as with the 4.9-litre Ballot, there is no direct link between the average speed capabilities of the 1920-l 3-litre Grand Prix cars and their predecessors of 1914. At a critical period in automobile design we are thus deprived of incontrovertible figures and have once again to rely upon deductions from performances at Indianapolis and at Brooklands. Some relevant lap speeds on the former track may be summarised thus :

1913 Grand Prix Peugeot	99.85 m.p.h. (100)
1914 Grand Prix Peugeot	98.5 m.p.h. (98.8)
1919 Ballot	104.7 m.p.h. (104.8)
1921 Ballot	100.75 m.p.h. (101)

At Brooklands we have :

1913 Peugeot	105.97 m.p.h. (100)
1919 Ballot	112.17 m.p.h. (106)
1921 Ballot	107.34 m.p.h. (101.2)
1922 Vauxhall	108.27 m.p.h. (103)

(The figures in parentheses give the percentage position.)

The performance factors of the Vauxhall and Ballot cars are remarkably similar, the b.h.p. per sq. ft. being 9.3 and the output per ton 95 and 98 b.h.p. respectively. For this reason, although the Vauxhall did not compete in a Grand Prix we are justified in using some known statistics regarding its performance as a yard-stick. These are :

Standing kilometre	69.75 m.p.h.
Standing mile	78.69 m.p.h.
Inferred average kilometre to mile	95.5 m.p.h.
Maximum speed .. .	111.85 m.p.h.

(6/10,25: A.I.; No. 7)

It will be observed that the maximum speed is 6 per cent below that of the 4.9-litre Ballot *supra.*

Let us now sum up. The Indianapolis lap speeds of the 1921 Ballot were between 1 and 2 per cent better than the 1913-4 Grand Prix cars, but 4 per cent slower than the 1919 straight-eight Ballot. The Brooklands figures tell a somewhat similar story for the Ballot was 2 per cent faster than the 1913 Peugeot and a little under 5 per cent slower than the 1919 Ballot. Assuming the Vauxhall and the 3-litre Ballot to have comparable maximum speeds they were both about 5 per cent slower than the 1919 Ballot.

We have already established an average speed index of 118.5 for the larger car, and on the basis of the above figures it would seem fair to assume that the 3-litre models were 6-7 per cent slower in maximum speed or 2½-3 per cent inferior in average speed capabilities. On these admittedly somewhat tenuous grounds we may argue that the correct index for the 3-litre cars of 1921-2 (Ballot, Duesenberg and Vauxhall) was 15 per cent better than the 1906 winner, and that they were faster than any cars built up to that time, the 4.9-litre eight-cylinder Ballot alone excepted.

In 1922 and 1923 the 2-litre Fiat cars were dominant, firstly with their steel-cylindered, roller-bearing sixes, which triumphed at Strasbourg and had a walkover at Monza, and in the following year with their eight-cylinder supercharged models of basically similar design which broke down in the French Grand Prix but once again scored an easy win in Italy.

It is, unfortunately, impossible to establish directly how the performance of the Fiat compares with previously built Grand Prix cars as it ran in only two races, and those on circuits not previously used. We can, however, make a very close estimate of the performance in theory and also in comparison with cars of similar weight, frontal area and maximum power.

It is fair to calculate that a car with 7.6 h.p./sq. ft. would have a maximum of 105 m.p.h., and we can check this estimate against the performances of 1½-litre supercharged engines of similar design and output fitted with similar bodies. The four-cylinder 1923 Fiat, 1½-litre, for example, was almost a replica of the previous year's six-cylinder Grand Prix car and lapped Brooklands at 101.64 m.p.h. The 1924 Talbot Darracq developed 102 b.h.p. and with 8.5 h.p. per sq. ft. lapped Brooklands at 106 m.p.h., whilst a single-seater version of this make and type achieved 114.71 m.p.h. over a flying kilometre (31/8/25, A.I.5).

From these facts we can infer that the maximum speed of the Strasbourg Fiat could not have been more than 110 m.p.h. and is certain to have been over 102 m.p.h. To take the mean between these, 106 m.p.h., is almost certainly a very close approximation to the truth. The inferred average speed index brings us to a figure of 111, and with the 5 per cent allowance for front-wheel brakes, makes the car slightly slower than the 1914 Grand Prix winner. Technically, this may be considered a satisfactory result, bearing in mind that the engine size had been diminished 65 per cent measured in terms of capacity and 26 per cent measured on piston area.

Fiat supremacy, decisive in effect, was brief in time, and in 1924 Sunbeam and Alfa Romeo shared the honours.

Both Bugatti and Delage continued with their previous types of car running unsupercharged and paid the inevitable penalty of deficiency in horsepower ; the Delage giving 120 b.h.p. and the Bugatti about 90 b.h.p. The Sunbeam and Alfa Romeo engines, however, both developed approximately 140 b.h.p., and we can make an interesting and direct comparison between the 1922 Fiat and the 1924 Sunbeam since, with the exception of supercharging, they are of almost identical design and were developed by the same engineer. The data table reveals that the Sunbeam engine developed 50 per cent more power, 36 per cent greater b.m.e.p. and 40 per cent more h.p. per sq. in. of piston area.

The P2 Alfa Romeo had a similar performance, and whereas it is certain that

the 1922 unsupercharged 2 litres did not exceed 110 m.p.h., the Alfa Romeo was timed over ten kilometres at 123 m.p.h. at the beginning of 1924.

When this make of car ran on the Monza track at the end of 1924 the lap speed was 4.2 per cent greater than the supercharged Fiat, and this brings the average speed index for the car to 120. Earlier in the year at Lyons, however, the Sunbeams were 1¼ per cent faster than the Alfa Romeos, and we are, therefore, justified in raising the speed index for the British car to 121.

From 1922 onwards there is little difficulty in establishing comparative average speeds, since first Monza and later Montlhery and the Nürburg Ring give us a means of directly comparing the performances of cars of different types and year of construction. The French Grand Prix of 1925 is a particularly interesting example. Sunbeams were practically unchanged from the previous year, but Alfa Romeo had found an additional 20 h.p. by careful detail development, whilst Delage attained perhaps the peak of 2-litre performance by adding a supercharger to their twelve-cylinder car. This design had already the advantage of some 20 per cent greater piston area than either Sunbeam or Alfa, and at Montlhery it proved itself the fastest car, the relative speeds being : Delage 100 ; Alfa Romeo 99.6 ; Sunbeam 94.8.

The very large speed differences between the French and Italian cars and Sunbeam is in harmony with a deficiency of some 50 b.h.p. and the margin between the Sunbeam and the Delage on this circuit brings us to an average speed index of 127.5 for the latter.

It is not uninteresting at this stage to insert a check upon the formula in which it was suggested that average speeds on a circuit varied (with road-racing cars of comparable types) as the square root of their maximum speeds. Conversely maxima should vary as the square of the lap speeds, and in the 2-litre class we have estimated these (relative to the 1906 Renault) to be : 1922 Fiat 111 ; 1923 Fiat 116 ; 1924 Alfa Romeo 120 ; 1924 Sunbeam 121 ; 1925 Delage 127.5.

We have a timed 123 m.p.h. for the 1924 Alfa Romeo, and giving a slight benefit to the Sunbeam, we can fix the speed of the latter at, say, 125 m.p.h. Using this as a datum we get, working backwards, maxima of 115 m.p.h. and 105 m.p.h. for the 1923 and 1922 Fiats and, forwards, 138 m.p.h. for the 2-litre Delage. The former figures agree very closely with the estimates that have been made ; the latter compares with 134 m.p.h. in record attempts (A.I.7., 5/9/26) That we should be able to use an empirical formula of this kind to cover a racing period of twenty years with such diverse types as the 1906 10-litre Renault and the 1925 2-litre Delage and to predict the maximum speed of the latter within an accuracy of 2¼ per cent is surely worth noting.

Perhaps even more remarkable is the accuracy with which one can predict the maximum speed of the Renault knowing (a) the maximum speed of the Delage and (b) the average speed indices of the two cars. The Renault index was established as 100 and the Delage 127.5 but the latter includes a 5 per cent allowance for front brakes. Eliminating this brings the index figure to 121 which in turn should be the equivalent of a 48 per cent increase in maximum speed, i.e., the Renault ought theoretically to have a maximum speed 32.5 per cent less than the Delage. This fraction deducted from 134 m.p.h. gives a figure of 90.5 m.p.h. which is less than the 2 per cent below the 92.2 m.p.h. actually recorded by the Renault when running in the 1906 Grand Prix.

Record attempts enable us to state precisely the relative performances of the best examples of 1925 and 1926-7 period, for we have figures relating to both the twelve-cylinder Delage and the eight-cylinder Talbot. The former have previously been quoted ; the latter achieved 81.55 m.p.h. for a standing kilometre, 92.33 m.p.h. for a standing mile, and 129.75 for a flying kilometre, from which we may deduce that the speed between the end of the kilometre and the mile averaged 120 m.p.h. (A.I. No. 10, 5/9/26).

There was little to choose between the all-round performance of the Talbot and Delage cars, and the square root formula derived from an average speed index of 127.5 for the 2-litre twelve-cylinder Delage, gives an estimate (based on maxima) of 125.5 for the l½-litre models.

Direct comparisons can be made between lap speeds put up at Montlhery, Monza and San Sebastian but there are good reasons for ignoring published figures for the last-named circuit. In 1925 the twelve-cylinder Delage cars led the race throughout and on other circuits proved beyond question that they had superior speed to the unsupercharged Type 35 Bugattis. Nevertheless, at San Sebastian, the Bugatti put in a lap at 82.75 m.p.h., whereas the best recorded Delage figure was 81.5 m.p.h.-a fairly clear indication that the Delages were not pressed. Restricting our comparisons to the remaining two circuits, we can compare the 1924 Alfa Romeo lap of 104.24 m.p.h. at Monza with the 103.2 m.p.h. recorded by one of the Talbots when running in 1928. This gives a Talbot index of 125.5 which agrees exactly with the calculated figure.

In the French Grand Prix of 1927, at Montlhery, the Talbot attained an index of 127.8 by almost equalling the record lap put up by the 1925 2-litre Delage, whereas the l½-litre Delage exceeded the speed of its predecessor by 1.8 per cent and must therefore be given an average speed index of 129.2. Owing to the absence of data it is impossible properly to assess the average speed capabilities of the double-six Fiat, but it was almost certainly faster than the Delage and rough justice will probably be accorded the three most powerful makes built under the 1½-litre formula by giving indices of 128, 129 and 130 to the Talbot, Delage and Fiat cars respectively. Putting the matter in another way, by reason of superior brakes, road holding and general control, these models beat calculated form by between 3 and 4 per cent, i.e., their improved chassis design gave results equal to a potential gain of 10 m.p.h. in top speed, so one may say that between 1925 and 1927 developments in road holding proved to be worth 40 h.p.

The Type 35 Bugatti was 7 per cent slower than the 1925 Delage in maximum speed and the calculated average speed index would, therefore, be 123, viz. 4½ per cent less than the Delage.

Between the Bugatti and the Talbot the difference is 4 per cent on maximum or an implied 2 per cent on the average speed index, but when these two cars met on level terms at Monza in 1928 the Bugatti was only a mere 0.5 per cent slower on lap speed, whilst on the San Sebastian circuit it was actually 4 per cent faster than the I½-litre, eight-cylinder, Delage, which for all practical purposes may be considered to have the same performance as the Talbot of corresponding capacity.

The relation between the 2.3-litre Bugatti and the 1925 2-litre cars is rather more difficult to establish. We can set up a table thus showing the speed relative to the P2 Alfa Romeo on three circuits. These are :

Monza	0.96 *per cent*	
Montenero	4.0 *per cent*	Bugatti deficiency
Trefontana	2.8 *per cent*	

We must, however, enter a *caveat.* The comparison at Monza is as between Alfa Romeo in 1924 and Bugatti in 1928, whereas the other two figures are based on Alfa Romeo performances in 1928-30, and in these years there is no doubt that the P2 was a good deal faster than it had been previously.

This is shown most clearly at Cremona. On its first appearance on this course in the early part of 1924 the P2 averaged 98.3 m.p.h. for the race ; in 1929 114.4 m.p.h. On the face of it it would appear that the Alfa average speed index rose from 121 to *circa* 140 in five years, but it is more likely that the car was not flat out in its maiden race in 1924. The maximum speed timed over ten kilometres increased from 123 m.p.h. to 138 m.p.h., which would lead one to expect that the index would rise from 121 to 131.6.

The 1930 Monza race gives a cross-check for on the short circuit used for this year the P2 Alfa proved itself 3 per cent faster than the eight-cylinder Talbot, and thus can claim a comparative average index of not less than 130.

Accepting, then, this figure for the fully developed P2 (developing 165 b.h.p.) we shall certainly not be far wrong if we place the Bugatti index at 127, that is four points above the figure predicted on the basis of known maximum speed.

These virtues kept the car in active competition with the higher powered models, of much more complicated engine design, built between 1924 and 1927, but in the 1930 Monza race the 2½-litre Maserati proved itself definitely the fastest road racing car built up to that time. The average circuit speed was no less than 7½ per cent faster than the Type 35C Bugatti, and even on the San Sebastian road course, perhaps a truer guide of relative merit, the Maserati was 3 per cent the faster car. On the Brooklands Mountain circuit the difference in speed between the two types was 72.6 m.p.h. and 78 m.p.h. and we are certainly justified in giving Maserati an average index of 133.

If the relation of average index to square root of the maximum speed were immutable the top speed of Maserati would have been 7 per cent more than the twelve-cylinder Delage or approximately 144 m.p.h. There are, unfortunately, no records to show the true maximum of the Italian car, but we can be certain that it was not so fast as this and we may doubt if it would reach 140 m.p.h.

In the next three years racing cars continued to be disproportionately faster round a circuit than they were on a straight line.

Chassis showed little visible change from 1929-30 but developments were continuous and figures for average speeds show clearly that these were worth up to a gain of over 5 m.p.h. in maximum.

The maximum speeds of the 1931 models were as one might expect, and the validity of the square root law is supported by the known facts. The 92 m.p.h. 1906 Renault had approximately 18 sq. ft. of frontal area and 90 b.h.p. ; the Type 51 Bugatti had a frontal area of some 11 sq. ft., and an engine output of some 160 b.h.p. Postulating that 5 b.h.p. per sq. ft. gives 92 m.p.h., 14.5 h.p. per sq. ft. gives a calculated maximum speed of 131 m.p.h. ; and the best timed figure for the Type 51 was actually 131.22 m.p.h. over the flying kilometre (10.3.32 AI No. 181).

Both the Monza Alfa Romeo and the Maserati had similar frontal areas but rather higher maximum power, the latter developing a claimed 175 b.h.p. equal to a theoretical maximum of about 136 m.p.h.

It will be recognised that this figure is less than that obtained on the 1925 Delage of 25 per cent lesser swept volume, but which had twelve cylinders compared to eight and a piston area of 38.7 sq. in. in place of 41.3 sq. in., a deficiency of 6 per cent, which was more than offset by the more ambitious layout. In consequence, the road racing cars built in 1932 were very little faster than the 1925 Delage flat out, and using square root law we are not entitled to expect that their average index would be more than 129. Direct comparison with previous cars over similar circuits proves that the real figures were much better than this.

From 1930 onwards there is a steady increase in the number of comparisons which can be made between different cars running over the same circuit and in order to exemplify the technique of establishing average indices the figures for the 1931/2 Type 51 Bugatti, the 1931 Monza Type Alfa and their immediate successors, viz. : the 1932 P3 Alfa Romeo Monoposto and 1933 2.9 Maserati, are set out in a table below. This shows average m.p.h., with average indices in parentheses, and where the latter have been established in data already quoted the figures are italicised.

EVIDENCE OF LAP SPEEDS 1925-33

	COURSE ; LAP SPEED (M.P.H.) ; AND AVERAGE INDEX.						
Make	*Spa*	*Montlhery*	*Pescara*	*Nürburg*	*San Sebastian*	*Monza*	*Rheims*
Alfa Romeo P2 1925	81.5 (126)					104.24 (126)	
Delage 1925		80.3 (127)					
Bugatti Type 35 1928-30				69.97 (127)	88.25 (127)		91 *(127)*
Maserati 2½ Litre 1930			78.3 (131)		91 (131)		
Monza Alfa 1931			83.4 (138)			105 (127)	
Type 51 Bugatti 1931-2	88 (136)			72.6 (132)			92.78 (129.5)
2.8 Maserati 1931		85.6 (135.5)					
P3 Alfa Romeo 1932-3				77.55 (141)		115.82 (140)	99.5 (139)
2.9-Litre Maserati 1933	92.33 (143)	86.6 (137)			96.59 (139)		

Note : The Monza speed of the P2 Alfa Romeo was achieved in late 1924 and the average index has been correlated not with prior performances in 1924 but with subsequent speeds in 1925.

On the mean of the above we can award average indices as follows :

1931-2 Type 51 Bugatti -132.5
1931 Monza Type Alfa -132.5
1931 Maserati -135.5
1932/3 P3 Alfa Romeo -140
1933 2.9-litre Maserati -139.9

The figure for the 2.8 Maserati is based on its performance on one circuit only, and may be something of an exaggeration, but this car beat both the Monza Alfa and the Type 51 Bugatti in the 1931 Monza Grand Prix and its margin of speed over the whole race was 1.35 per cent higher than the Alfa Romeo, which compares reasonably with the lap speed index margin of 2¼ per cent.

The lap speeds achieved by the Type 51 Bugatti and the Monza Alfa Romeo (where the average indices are supported by ample consistent data on road racing circuits) presuppose a maximum speed 58 per cent higher than the 1906 Renault, i.e. 146 m.p.h., after making due allowance for front brakes. This is 10 per cent more than they reached in fact.

In the succeeding cars, that is to say the P3 Alfa Romeo and 2.9-litre Maserati maximum recorded speeds again agree closely with expectations based on the power available, but the gap between them and the top speeds indicated by performances on a lap has grown even wider.

On the basis of h.p. per sq. ft. of frontal area one would expect the P3 Alfa Romeo to have a maximum of 143 m.p.h. and this must be very nearly a true figure since the car had a normal gearing giving 140 m.p.h. at the peak of the power curve. On the assumption that maximum speeds vary as the square of the average index we should, however, expect a top speed of 162 m.p.h. using the 1906 Renault as a datum, or 152 m.p.h. using the Type 35 Bugatti as a starting point. In other words, in 1930 the Bugatti was beating the " square law " by a margin ; in 1932-3 the P3 Alfa Romeo beat it by an even bigger margin which can be reckoned as 6 per cent, or 11 per cent compared with the rear-braked Renault.

We now come to one of the outstanding paradoxes in the technical history of automobile racing. Between 1928 and 1933 we have seen a steady and indeed substantial growth in average speeds with but small changes in maxima and with very little visible signs of change in design. In 1934 racing car performance factors were subject to a violent upheaval as engine outputs were raised by 50 per cent or more, maximum speed increased by over 20 m.p.h., weight if anything reduced. Simultaneously came the introduction of independent suspension for each wheel on the German cars.

The very large increase in performance factors coupled with the acknowledged merits of independent wheel suspension would lead one to expect a very considerable gain in the average speed index for 1934.

Taking first the orthodox Alfa Romeo which had a 1933 index figure of 140, one might expect the additional power to raise this to 142.5 and on similar theoretical reasoning that the German cars would lap sufficiently fast to justify an index figure of 154. A study of the lap speeds set out in Volume I demonstrates that the Alfa Romeos ran very close to form ; for using the same method of assessment as was disclosed in detail in the preceding table the Alfa Romeo P3 Type B index for 1934 comes to 143.5. The Type 59 Bugatti proved slightly faster than the Alfa Romeo and its speed in the Belgian, Swiss, and Spanish Grands Prix brings us to an average index of 144.5.

There are no facts which give us directly the maximum speeds of any of the 1934 racing cars for although some speeds based on times taken over a kilometre at Pescara were published, these are so palpably optimistic that one must reject them either on the grounds of error in measurement or by reason of some very special circumstances.

Assessing the road performance of the German cars is also far from easy for they took some time to settle down and discover correct tyre pressures, shock absorber settings, etc. Hence in the early races they showed only little or no superiority in performance over the more conventional and far slower models, and on figures for Montlhery and Nürburg achieved in June the German cars have an average index of no more than 145. In the later races such as at Monza and San Sebastian in September they achieved superiority over their rivals, bringing the index figure to 150. The details are worth setting out :

Lap time comparison 1934 Grand Prix cars

Circuit	*Car*	*Lap Time*	*Relative speed*	
Montlhery	Alfa Romeo	5mins. 6 secs.	100	June
	Mercedes-Benz	5 .. 6.3 ..	99.9	
Niirburg	Auto Union	10 .. 44 ..	100	
	Alfa Romeo	10 .. 56 ..	98	
Monza	Auto Union	2 .. 13.6 ..	100	Sept.
	Mercedes-Benz	2 .. 16 ..	97	
	Alfa Romeo	2 .. 19.2 ..	93	
San Sebastian ..	Auto Union	6 .. 20 ..	100	
	Bugatti	6 .. 27 ..	98	

The highest average index which can be given to the German cars was 152 for Auto Union and 148 for Mercedes-Benz (both at Monza). This is of particular interest for it shows that independent suspension did not bring any direct benefit although it undoubtedly gave advantages in respect of stability at speed and improved acceleration away from corners. It seems likely, however, that the conventional sprung Alfa Romeos and Bugattis circumnavigated sharp radius corners faster than their independently sprung rivals, and this supposition is confirmed by some most interesting times taken by Faroux at Monza and published in his paper *l'Auto*. At the Italian Grand Prix he observed a kilometre equally divided by approach to, and departure from, the apex of a hairpin corner and the times taken (converted to average m.p.h.) were :–

Times and Speeds over 1 km. at Monza, 1934

Car	*Braking Time and average speed 500 Metres*	*Accelerating Time and speed average 500 Metres*	*Total time and average speed over 1.0 km. with hairpin corner*
Auto Union	12.4 secs. 90 m.p.h.	14.4 secs. 77.5 m.p.h.	26.8 secs. 83.5 m.p.h.
Mercedes-Benz	12.6 secs. 88.5 m.p.h.	14.8 secs. 75.5 m.p.h.	27.4 secs. 81.5 m.p.h.
Alfa Romeo	12.0 secs. 93 m.p.h.	15.6 secs. 71.6 m.p.h.	27.6 secs. 81.0 m.p.h.

In round figures Alfa Romeo averaged 6 m.p.h. less than the Auto Union and 4 m.p.h. less than the Mercedes-Benz, over the 500 metres away from the corner, but over the entire kilometre was only 2.5 and 0.5 m.p.h. slower than its more powerful rivals. It is improbable that the brakes of the Alfa Romeo were the most effective of the three cars and a simpler and more likely explanation is that the P3 took the corner at the highest speed.

Although the 1935 Alfa Romeo was a faster and more powerful car than the 1934 model it remained basically inferior to the German cars with an anticipated maxima of about 155 m.p.h. compared with about 180 m.p.h. Correspondingly, one would expect that with a 10 m.p.h. gain in speed over the 1934 model (7 per cent) the lap index would rise by 35 per cent to 149. That is to say, one would expect a 1935 Alfa Romeo to put up about the same lap speeds as the 1934 Mercedes-Benz and Auto Unions. This proved to be so on the Nürburg Ring for, in winning the Gerrnan Grand Prix, Nuvolari lapped at 79.3 m.p.h. which can be considered identical with the speed put up in the previous year's event by the Auto Unions.

In both the French and Italian Grands Prix, run over circuits with artificial corners, Alfa Romeo proved faster than either of the German cars but the latter asserted their superiority on 100 m.p.h. circuits such as Spa and San Sebastian.

Mercedes-Benz put in a lap giving a comparative average index of 157 on the former circuit and Auto Union equalled this figure on the latter, but making a comparison of all the courses on which the cars can be fairly compared the index figure is 153 for both cars. Thus in 1935, as in 1934, the German cars failed to reach the figures which might be theoretically expected from them, viz. : between 158 and 160. Alfa Romeo, on the other hand, were as fast or perhaps faster than one might expect in view of their more moderate maximum speed.

One concludes that the Italian car made full use of all the power available but that chassis design had not yet progressed sufficiently far to enable the full reward of 400 b.h.p. to be reached in road racing. In particular, both Mercedes-Benz and Auto Union were hard to handle on short-radius curves which led the team drivers of the former to ask for a shorter wheelbase car. The Auto Union presented special handling problems of its own, for the drivers were placed very far forward and were thus in a difficult position to sense the beginnings of a back-wheel skid. Moreover, the use of swing axle with high roll centre and stiff rear springs produced cars which were inherent oversteerers and this, coupled with the great power under the bonnet, imposed a degree of discretion on the drivers which must have adversely affected lap speeds.

These facts should not blind us to the practical reality that the German cars had raised lap speed averages by some 10 per cent in two years whereas in the ten racing years 1924-33 the lap speed index had risen from 127 to 140, an average increment of 1 per cent per annum. Hence under the 750 kg. formula ten years of normal average gain were telescoped into two, and one has only to compare the 450 b.h.p., 175 m.p.h., vehicles of 1935 with the 180 b.h.p., 135 m.p.h., cars built only three years previously to realise that the racing car design had undergone complete metamorphosis.

In 1936, the 1935 cars themselves were made to seem under-powered vehicles, with moderate average speeds, despite the fact that the most successful model of the year, the C Type Auto Union, was no easy car to drive owing to the steering effects

caused by the swing axle system, and by the enormously large and heavy tyres essential to ensure a life of over 150 miles before a pit stop was necessary for their renewal.

These defects were minimised by the comparatively hard suspension with friction damping, but nevertheless with the great increase in power the C Type car not only won a very large number of races, but also set up entirely new standards of average speed. On the Nürburg Ring, for instance, the C Type was used unchanged in design for two years and in 1936 it proved to be $4\frac{1}{2}$ per cent faster than the B Type at Berne and 8 per cent faster than the A Type at Nürburg. In 1937 it was faster still.

On the basis of circuit speed varying with the sixth root of the h.p. per sq. ft., we should expect the C Type to be 10 per cent faster than the A Type and 6 per cent fasterthan the B Type, and during 1937 it did, in fact, prove exactly 6 per cent faster than the B Type on the Berne circuit, and (taking into account a remarkable practice lap) 10.5 per cent faster than the A Type on the Nürburg Ring. Using these percentage improvement figures we get an average index of 161 using a 1934 A Type as a datum, or 162.5 using the B Type 1935 model as a datum.

Compared with other known performances at Spa and Brno the C Type returned an index figure of 163 in 1937 and we may reasonably accept 162 as a fair figure of merit for this design. Taking into account the 11 per cent correction factors already touched upon we would thus expect the Auto Union to be faster than the 1906 Renault in the proportion of 2.1 : 1 equal to a maximum speed of 189 m.p.h. On the Pescara circuit two of these cars were timed at 183 m.p.h. and on the normal gearing used for road races the peak of the h.p. curve was reached at 185 m.p.h. The divergence between theory and practice is, therefore, less than 2 per cent, and whereas the 1934-5 cars had failed by an appreciable margin to reach the circuit speeds which might be expected from them, the 1937 C Type entirely lived up to expectations, at least when it was driven by the gifted Rosemeyer.

The 1937 Auto Union performance was far ahead of anything that could be achieved by Alfa Romeo, who continued with their twelve-cylinder engine in the all-independently sprung 1936 chassis. This proved to be 4 per cent slower than the C Type Auto Union in practice on the Nürburg Ring and 5 per cent slower in practice on the Leghorn circuit. Even the introduction of a new chassis with a much lower centre of gravity failed to bring Alfa Romeo into the picture during the 1937 racing, and during the whole of the year they failed to get into the first three positions.

The average speed index of the 1937 Italian cars was, in fact, about 155 (compared to a 1936 figure which can be established at about 152), but an advance of this order was quite inadequate to deal with the Auto Union C Type, and even more hopeless as competition with the Mercedes-Benz Type W125.

This car had the highest performance factors of any yet constructed, and the 646 h.p. developed by the engine is by far the greatest which any designer has asked his team drivers to control on a road racing circuit. The Auto Union, although not hopelessly outclassed, was definitely inferior during this year, the mean advantage of the Mercedes-Benz being 1.4 per cent (giving it an overall figure of 163.4) and the relative lap speeds being as shown in the following table.

BEST LAP SPEEDS C TYPE AUTO UNION AND MERCEDES-BENZ TYPE WI25 CARS

	Auto Union C Type	Mercedes-Benz W125
Spa	107.7 m.p.h.	109.9 m.p.h.
Nürburg	87 ,,	86.2 ,,
Berne	106.8 ,,	107.14 ,,
Brno	92.8 ,,	94.89 ,,

In 1938 the regulations excluded the 600 h.p. " monsters " which had developed during the years of the 750 kg. rating and led to cars with 3-litre supercharged engines. These used more fuel than their predecessors and hence left the starting line not only with less power but also weighing more.

In the first year of the new formula the Auto Union D Type suffered a series of misfortunes and the twelve-cylinder Mercedes-Benz Type W154 was beyond doubt the fastest of the year.

Although handicapped in acceleration and maximum speed factors the W154 fractionally improved on the lap speed of its predecessor on the Berne and Leghorn circuits. At Nürburg and Donington the 1938 3-litre cars were slower by 1.9 and 0.15 per cent respectively. Comparative figures on the Rheims circuit used for the French. Grand Prix can only be made with the P3 Alfa Romeos of 1932 and 1935, and these give an index figure of approximately 155. It should, however, be noted that this was the first major race of the season and that Mercedes-Benz had no serious opposition, so it is likely that this speed underrates the true capacity of the model, which in the face of other performances, merits an index figure of at least 160 and an anticipated maximum speed of 188 m.p.h. As can be seen from the specification table reproduced in Example No. 17 (Volume I) this was the figure obtained at 7,500 r.p.m. on the gear ratios used at Nürburg, although a basis of speed varying as the cube root of power per sq. ft. of frontal area the predicted maximum of the Type 154 would be only 180 m.p.h. Thus both in comparison with the higher power of the 1937 car, and absolutely, the Type 154 was substantially faster round a circuit, and flat out, than one might theoretically expect.

Performance factors for the 1939 Auto Unions were 405 b.h.p. per laden ton and 42.2 b.h.p. per sq. ft. of frontal area ; the Mercedes-Benz W163 disposed of 405 b.h.p. per laden ton and 39 b.h.p. per sq. ft. In theory, therefore, the rear-engined car should have secured a slight advantage in circuit performance ; in fact it failed to do so, as shown below :

BEST 1939 LAP SPEEDS D TYPE AUTO UNION AND W163 MERCEDES-BENZ

	Auto Union	Mercedes-Benz
Nürburg	84.7 m.p.h.	87.5 m.p.h.
Rheims	116.6 m.p.h.	117.5 m.p.h.
Berne	103.3 m.p.h.	106.23 m.p.h.

These figures give a mean superiority to Mercedes-Benz of 2.3 per cent.

In assessing the absolute performance of the W163 we find that it was 1.5 per cent faster on the Nürburg Ring and 0.45 per cent slower at Berne. We have previously established an average index figure of 163.4 for the W125, and on the Rheims circuit the best practice lap gives the 1939 Mercedes-Benz an index of 166, using the P3 Alfa Romeo as a datum. Although this is high in relation to performance at Spa and Berne it agrees almost exactly with the average ascertained by comparison with the W125 on the Nürburg Ring.

Giving full weight to this identity of evidence provided by lap speed on a very difficult and comparatively slow course, confirmed by the average on an extremely fast open course, we may fairly award the W163 an index of 165. The 1939 3-litre V12 two-stage boost Mercedes-Benz may, therefore, claim to be the proved fastest road-racing vehicle to be built in the period reviewed by this book, a matter of considerable technical interest in that the basic performance factors of this car were considerably lower than those of the 1937 models. This apparent anomaly can be accounted for, but to do so involves an analysis of quantities and qualities which will be more appropriately dealt with in the chapter dealing with overall trends in design between 1930 and 1939 in Part IV.

During 1938 and 1939 many responsible people advocated the replacement of the existing Formula (3 litres supercharged, 4½ litres unsupercharged) by a 1½-litre limit. The traditional reasons were advanced for such a change ; that is, it was represented that the existing cars were too fast for most drivers ; that they were excessively costly to build and operate ; and that competition was confined to two makes of only one nationality.

In 1946 such arguments had become irrelevant and the establishment of a 1½-litre category for Grand Prix racing was determined as much by *force majeure* as by reason or logic. None of the pre-war 3-litre cars were available for racing, with the exception of the Alfa Romeo models, and as it had clearly been established in the pre-war years that the 4½-litre cars were no match for blown 3-litres, the proposal to give them a new lease of life by enabling them to compete against 1½-litre supercharged types was quite an appropriate one.

The introduction of this new limit for 1947 and, as originally planned, for the ensuing four years, made certain that average circuit speeds would fall. The extent of the drop could be estimated both inductively and deductively.

Taking the first method and arguing from the particular to the general, it was possible immediately to write down the performances put up by various cars eligible for the new Formula on certain European circuits in 1938 and 1939, and also to compare the speeds achieved thereon both with the immediate pre-war and earlier Grand Prix types. By making this comparison on three differing circuits, i.e. Livorno (or Leghorn), which had a rather slow lap, Rheims, representing the highest speed achieved in Europe, and Berne as an intermediate course, we can set out a table as follows :

M.P.H. SPEEDS OF 1½-LITRE SUPERCHARGED AND 4½-LITRE U/S CARS ON THREE EUROPEAN CIRCUITS (including practice)

Make and Type	*Berne*	*Rheims*	*Leghorn*
1939 Alfa Romeo	98.8	—	90.8
1937/8 E.R.A. C Type	91.4	101.6	—

Make and Type	*Berne*	*Rheims*	*Leghorn*
1939 E.R.A. E Type	—	101.6	—
Maserati 4 CL	97.0	99.6	—
Talbot 4-litre	—	105.8	—
Delahaye 4½-litre	—	100.3	—
1938 Mercedes-Benz	107.5	109.6	91.2
1939 Mercedes-Benz	106.4	117.5	—

From these figures we can infer that in 1939 the Alfa Romeo Type 158 was the fastest car of Formula I type and also that on a comparatively slow course, such as Leghorn, Charles Faroux was justified in putting up as a headline : " Les 1.500 allèrent presque aussi vite que les bolides . . .". Nevertheless, " Les 1.500 " were considerably slower at Berne and not, so to speak, in the same street at Rheims. Using these three circuits as a base we may arrive at lap speed index figures as follows :

Mercedes-Benz Type W. 163		. . 165
Alfa Romeo Type 158 . .		. . 150
Talbot 4-litre	In	. . 148.6
Maserati 4 CL	1939	. . 145.2
E.R.A. E Type	Form	. . 142
E.R.A. C Type . . .		. . 142
Delahaye 4½-litre . . .		. . 141

In the case of the Alfa Romeo allowance has been made in the above table for the fact that it did not run at Rheims. The E Type E.R.A. is probably underrated as this was its first public appearance, and the circuit at Rheims manifestly favours the cars with the highest maxima.

Generally speaking, however, it will be seen that on the basis of past results one could expect the 1947 cars to have a lap speed index lying between 145 and 150. They would thus be between 10 and 15 per cent slower than their predecessors and the fastest of them would have performances equivalent to those achieved by Mercedes-Benz and Auto Union in 1934. The slower cars would be equivalent in speed to the 1932 P.3 Alfa Romeo.

A deductive estimate of speed could have been made on the basis of power per sq. ft. of frontal area. The higher-powered 1½-litre engines of 1939 were developing about 230 h.p. and although the drivers were mounted centrally above a central propeller shaft it is fair to assume that the cars had a frontal area of *circa* 11 sq. ft. This being so, they would have 21 h.p./sq. ft. of frontal area, the reduction of this factor being therefore nearly 48 per cent as compared with an abatement of total engine power of 52 per cent. The consequence of such a reduction would normally be a fall in the maximum road speed of the order of 20 per cent (i.e. from about 195 m.p.h. to 155 m.p.h.), and one might reasonably expect that this in turn would lead to an 11 per cent.reduction in lap speed corresponding to a Py (or lap speed index) figure of 147.

The 4½-litre cars were developing some 200 h.p. and with a frontal area of 12½ sq. ft. the h.p./sq. ft. was 16 - a reduction of 60 per cent compared to pre-war performances. From this one might have deduced a fall in maximum speed of about 26 per cent and a reduction in average lap speeds of about 14 per cent, giving a Py index of 142.

It will be seen that whether argued from past practice, or on purely theoretical grounds, a reduction in highest recorded lap speeds of around 10 per cent and a reversion to 1934 performances could reasonably have been anticipated.

Immediately after the war Alfa Romeo raised the output of the Type 158 to 254 b.h.p. and to continue the deductive theoretical argument this should have led to a circuit index of 151. Turning from evidence to fact, the Spa circuit was lapped in 1935 at 103.7 m.p.h. by a 4-litre Mercedes-Benz with a Py figure of 150 and in 1946 by a Type 158 Alfa Romeo at 104.4 m.p.h.

In 1947, the first year of Formula I racing, it was hard to make accurate comparisons with pre-war figures. Alfa Romeo so clearly mastered the situation in Switzerland that they found it unnecessary even to equal their pre-war lap speed ; as the Grand Prix de 1'A.C.F. was at Lyons they did not choose to run at Rheims ; and in the Marne Grand Prix held over the Rheims circuit a Type 4 CL Maserati improved very slightly upon the pre-war performance of this model.

During 1948, new cars, such as the 4½-litre Talbot, the 1½-litre Ferrari and the 4 CLT or San Remo Maserati, came into the picture, and the two-stage Type 158 Alfa Romeo was even further developed. Additionally, racing drivers themselves were able to polish off the rust spots which had corroded their technique during the retirement enforced by the war. By the end of 1949 the general performance of the Formula I cars had become sufficiently established to make possible a detailed analysis of their performance in comparison with pre-war types,

In relation to the 1939 cars the Alfa Romeo Type 158 could be evaluated at Spa, Berne and Rheims ; the 4 CLT Maserati at Spa and Monaco ; and the single-stage Ferrari at Berne and Rheims. Further, the Ferrari itself could be assessed in relation to the 4 CLT Maserati at Lausanne, Silverstone and Zandvoort ; the Maserati with the E Type E.R.A. at Jersey, Silverstone and Goodwood ; and the 4½-litre Talbot to one of the types aforementioned at Monza, Silverstone, Lausanne and Brno. The two-stage Ferrari was represented by a single appearance at Monza. Computations so based on the best performances in the first three years of Formula I racing give results which may be tabulated :

AVERAGE SPEED 1947-9 RACING CARS, cf. 1938-9 3-litre MERCEDES-BENZ

Make and Type		*Relative average speed*
Mercedes-Benz 3-litre		100
Alfa Romeo Type 158 two-stage	1949	94.2
Ferrari two-stage	1949	93.0
Alfa Romeo Type 158 one-stage	1947	91.2
Maserati San Remo two-stage	1949	91.2
Ferrari single-stage	1948	89.0
E.R.A. two-stage E Type	1948	88.5
Talbot 4½-litre U/S	1949	86.5

Bearing in mind that before Formula I commenced the outlook was that speeds would recede to the line held by the 1935 cars, it may further be interesting to set out the relationship between the immediate pre-war and immediate post-war models in a further table, thus :

COMPARISON OF AVERAGE SPEED INDICES OF 1947-9 AND PRE-WAR CARS

Relative to 1906 Renault

Year	*Make and Type*	*Py Factor*
1939	3-litre Mercedes-Benz	165.0
1937	5.6-litre Mercedes-Benz	163.4
1939	3-litre Auto Union	162.5
1937	6-litre Auto Union	162.0
1936	6-litre Auto Union	158.0
1948	1.5-litre Alfa Romeo two-stage	155.7
1937	3.8-litre Alfa Romeo	155.0
1949	1.5-litre Ferrari two-stage	154.0
1935	4-litre Mercedes-Benz	153.0
1947	1.5-litre Alfa Romeo single-stage	150.0
1949	1.5-litre Maserati two-stage	150.5
1934	4.95-litre Auto Union	150.0
1949	1.5-litre Ferrari single-stage	147.0
1949	4.5-litre Talbot U/S	143.0
1932	2.65-litre P.3 Alfa Romeo	140.0

Continuing, it is possible to interpret these figures as the handicaps which would be needed on a circuit such as Rheims, and this can be directly compared with a similar estimate for the leading pre-war cars made in Chapter XXXI.

HANDICAP FOR 500 km. RACE ON 1939 4.85-mile RHEIMS CIRCUIT

Year	*Make and Type*	*Starting Allowance*
1939	3-litre Mercedes-Benz	Scratch
1949	1.5-litre two-stage Alfa Romeo	9 min. 30 sec.
1947	1.5-litre Alfa Romeo single-stage	16 min.
1949	1.5-litre Maserati two-stage	16 min.
1949	1.5-litre Ferrari single-stage	19 min. 30 sec.
1949	4.5-litre Talbot U/S	24 min. 30 sec.

As it happens, the high boost two-stage Type 158 Alfa Romeo, on which the above calculations were based, did not actually run in the Grand Prix de 1'A.C.F. held at Rheims in 1949, but the somewhat lower powered two-stage model took 14 minutes longer than the winning 1939 Auto Union would have done if the race had been held over the same distance.

As shown in the tables above, between 1947 and 1949 Alfa Romeo raised their lap speed index by about 2 per cent per annum of Formula I racing, and after retiring for a year they reappeared in 1950 with an improvement of the same order. This can be checked in two ways. Reference to the performances of the 1948 Alfa Romeo itself at Berne, Monza and Rheims brings a Py factor of 158.03 and reference to the 1937-9 Mercedes-Benz speeds at Beme, Monaco and Rheims gives an index of 158.8. A final figure of 158.4 for the Alfa Romeo makes it possible to set out a comprehensive lap

speed table for the other 1950 cars and this shows that the 4½-litre Ferrari became immediately a formidable rival with a Py of 158.2.

As there are limited possibilities in the development of an unsupercharged engine, and as the Type 158 had by 1950 been run through seven racing seasons, there was no reason to suppose that the 1951 speeds of Ferrari and Alfa Romeo would show any great increment over those of the previous years. The fact is, however, that Alfa Romeo were able to make the very considerable advance of 3.7 per cent and Ferrari of 3.2 per cent taken over the whole of the year's racing. A substantial change in the Spa circuit ruled out any comparison with 1939 vehicles thereon, but the 1951 models were appreciably faster than the 1939 types at Rheims and the Nürburg Ring, and only slightly slower at Berne, on which last circuit comparisons over the full race distance were vitiated by exceedingly bad weather.

The hypothetical margin of superiority of an Alfa Romeo Type 159 over the 1939 Auto Union at Rheims would amount to 9 minutes in a 500 km. race. It is equally interesting to compare the performances of the Ferrari with the pre-war German cars on the Nürburg Ring. The fastest race on the latter circuit over the full distance of 500 km. was 82.77 m.p.h. by Caracciola on the 1937 Mercedes-Benz, equal to a total elapsed time of 3 hours 46 minutes. Over the same distance the 1951 Ferrari would have taken but 3 hours 44 minutes. Putting the matter in another way, if the German and French Grands Prix of 1951 had been run on *formules libres* over 500 km. the Alfa Romeo would have led a 3-litre Auto Union over the line at Rheims by the substantial margin of 164 miles (nearly 34 laps) and the Ferrari equally would have led the 1937 Mercedes-Benz over the line at the Nürburg Ring by some 2¾ miles.

The complete evidence of lap speed indices for all the major contenders in 1951 Formula I events is again set out in tabular form, and it should be remarked that the figures based on individual laps give results at times at variance with those taken over complete races. The reason is that the speeds for the latter depend not only upon whether the fastest combination of car and man covered full distance, but also upon the degree of competition experienced during the last few laps.

Enough has, however, been said to show that whereas the Formula I cars started their careers with an estimated deficit in speed of 10 per cent compared with the pre-war types, they were for practical purposes equally as fast after five racing seasons. The degree of improvement was unequal in that a steady advance of two per cent per annum (the standard rate during the whole history of Grand Prix racing) was almost doubled during 1951.

It is very difficult to assess with accuracy the development in average speed of the Formula I cars in the years 1952 and 1953. They were not run over the classic courses and all we can say from the short distance events staged in 1952 is that the B.R.M. was 0.5 per cent faster on a lap than the works Ferrari. It is fair to assume that the 1952 version of the latter car was slightly faster than the 1951 model (Py factor 163.2) and we must therefore give the B.R.M. a figure of at least 164.

The evidence in 1953 was even more tenuous and it is particularly difficult to interpret in the case of the B.R.M., which is obviously far more suited to really fast courses than it is to circuits with many corners. At Albi, for instance, the B.R.M. lapped at 115.57 m.p.h. which compares with the 106.63 put up by Fangio on a 1950

Maserati. Using the latter car as a datum we have a figure of 161 for the B.R.M., whereas if we use the Talbot speeds on the same circuit as a comparison we get a figure of 169. A fair but empiric figure would seem to be 165 on a fast course and 160 on a slow one. The Ferrari, as represented by the Thin-Wall Special, proved on the whole to be a slightly faster car and may have merited an index figure in excess of 165. To sum up, the Formula I cars running in minor events in 1953 were almost certainly as fast as, and possibly faster than, the 1939 Grand Prix cars. They thus have a claim to be called possibly the fastest road racing cars the world has yet seen.

It was a reasonable anticipation that the acceptance of Formula II as the lirnit for Grand Prix races in 1952 would result in a substantial reduction in lap and race speeds. The anticipated drop in the case of a car like the Ferrari, in which a 2-litre *circa* 200 h.p. engine replaced a 4½-litre approximately 400 h.p. power unit in the same chassis, was of the order of 74 per cent, but the reduction in fact was rather less than this. A comparison between these similar cars over identical circuits gives us :

AVERAGE SPEED (m.p.h.) 1952 FORMULA II FERRARI COMPARED WITH 1951 FORMULA I FERRARI

Car	*Nürburg Ring*	*Rheims*	*Monza*	*Spa*	*Berne*	*Average*
1951 Formula I Ferrari ..	85:69	117.95	122.5	117.4	102.2	109.148
1952 Formula II Ferrari ..	84.4	110.04	122.04	114.83	97.19	103.6

It will be seen that the difference was 5 per cent, but as one might expect, this average for the year contains within itself considerable fluctuations. For example, on the Nürburg Ring the drop in speed was under 2 per cent, whereas at Monza it was as much as 8 per cent. This shows that the Formula II cars suffered particularly where sheer lack of engine power prevented them from working up to comparable maximum speeds. Although somewhat outside the strict frame of reference of this chapter, it is relevant to point out that owing to the lower fuel and power consumption of the Formula II cars there was far less difference in their overall race times than might be supposed from the difference in lap speeds. This can be seen by comparing the times in 1952 with those put up in 1951 on the Nürburg Ring representing a slow course, and on Monza as an indication of a very fast course. These figures are :

OVERALL RACE TIMES FOR 20 LAPS ON NÜRBURG RING (283 miles)

Ascari (4½-litre Ferrari)	3 hr. 23 min. 3.3 sec.
Fangio (1.5-litre Alfa Romeo)	3 hr. 23 min. 33.8 sec.
Ascari (Formula II Ferrari)	3 hr. 26 min. 55 sec.

OVERALL RACE TIMES FOR 80 LAPS ON MONZA (312 miles)

Ascari (4½-litre Ferrari)	2 hr. 42 min. 39.2 sec.
Ascari (Formula II Ferrari)	2 hr. 50 min. 35.6 sec.

The Formula II Ferrari can be evaluated with both the preceding Formula I models and competitive Formula II designs on unchanged circuits such as the Nürburg Ring, Monza, Spa and Berne, and on the slightly changed circuit of Silverstone. It can also be compared with other Formula II models at Rouen and Zandvoort, and taking the overall picture we can set out the indices for the 1952 cars as :

MEAN INDEX LAP SPEEDS OF 1952 FORMULA II CARS

Ferrari	155
Maserati	153.6
Gordini	152
Connaught	148.5
E.R.A. Type G	146.5
Cooper	145
H.W.M.	144.2

In 1953, the 1952 lap speeds were in every case exceeded, although we must ignore the times put up at Rheims owing to the substantial change made in the nature of the circuit. The figures tabulated show that in 1953, as in 1952, Maserati and Ferrari achieved an approximate equality, with Gordini building the third fastest, and Connaught the fourth fastest, Formula II models. The mean index of the Ferrari is similar to that built up for the 1950 Alfa Romeo and as these figures are for the moment the endpoint in a study stretching over fifty years it may be of interest to compare these two cars circuit by circuit, and to put in parentheses the theoretical speed which would have been achieved by the 1906 Renault running on the same course.

RELATIVE RECORDED LAP SPEEDS FOR 1950 ALFA ROMEO FORMULA I CAR AND 1953 FERRARI FORMULA II CAR WITH THEORETICAL SPEED OF 1906 GRAND PRIX RENAULT

Car	*Silverstone*	*Monza*	*Berne*
1950 Alfa Romeo Formula I	98.2	118.83	100.47
1953 Ferrari Formula II	97.57	114.86	101.72
1906 Renault Grand Prix car	(61.8)	(72.6)	(64.4)

Finally one may estimate that if the 1939 Mercedes-Benz, 1953 Ferrari " Thin-Wall ", and 1953 B.R.M. had been running on the 1906 Le Mans circuit (which was the triangle Le Mans ; St. Calais ; La Ferté Bernard ; and then on the Paris-Le Mans Road) they would certainly have lapped at 120 m.p.h., and in view of the long straights, perhaps as fast as 130 m.p.h.

BEST RECORDED LAP SPEEDS AND MEAN AVERAGE SPEED INDEX FOR FORMULA I RACING CARS

Car	*Nürburg Ring*	*Good-wood***	*Spa*	*Monaco*	*Silver-stone*	*Zand-voort*	*Rheims*	*Monza*	*Jersey*	*Geneva*	*Barce-lona*	*Berne*	*Mean Index*
Alfa Romeo 158/9 ..	85.69	97.36*	120.51	64.56* (158.4)	99.8	—	119.99	124.53	—	83.7* (158.4)	104.46	104.46	164.4
Ferrari 4.5-litre	85.69	95.2*	117.4	—	100.65	—	117.95	122.5	—	82.2	108.1	102.2	163.2
Ferrari 1.5-litre 2-stage ..	—	—	110	63.4	—	—	—	—	—	—	—	98	154.4
Ferrari 3.3-litre	—	—	108.9	—	—	—	—	—	—	—	—	—	150.7
Lago Talbot	—	—	110	62.4	92.85	83.9	110.2	108.6	—	79.2	92.2	95.2	150.0
Maserati 2-stage	—	89.26*	—	62.6	92.3	83	105	108.3	94.43	74.5	94.8	98	148.6
Ferrari 1.5-litre 1-stage ..	—	—	—	—	91.2	81.6	—	104.2	94.2	—	—	—	144.9
E.R.A. B type . . .	—	85.38*	—	—	92.85	—	—	104.3	92.6	—	—	—	143.8
B.R.M.	—	88.7*	—	—	94.5	—	—	120.4	—	—	94.9	—	154.6
Simca Gordini 1.5-litre 1-stage	82.30	—	—	58.2	—	—	103.8	110.3	—	—	92.2	—	149.3

* 1950 models. ** Old course without *chicane*.

BEST RECORDED LAP SPEEDS AND MEAN AVERAGE SPEED INDEX FOR 1953 RACING CARS

Car	*Nürburg Ring*	*Silverstone*	*Albi*	*Rheims**	*Monza*	*Spa*	*Berne*	*Mean Index*
Maserati	84.6	96.67	—	115.9	114.76	117.3	101.72	158
Ferrari	85.62	97.57	—	115.9	114.86	115.5	101.4	158
Gordini	82.2	94.08	107.2	112.9	112.0	112.0	99.4	153
Connaught	77.6	94.08	106.4	110.4	110.1	(98.8)**	—	150.6
Cooper Alta	79.2	—	—	108.1	111.2	—	—	148.13
Cooper Bristol	76.38	94.08	100.0	107.2	108.4	—	95.0	146.9
H.W.M.	—	90.84	—	105.3	102.1	109.5	92	145.2

* Shortened, faster circuit used first in 1953. ** Ignored ; no " works " drivers.

Part Four

ANALYSIS AND SYNTHESIS

" The knowing more to-day than we knew yesterday ; the understanding what before seemed obscure and puzzling ; the contemplation of general truths, and the comparing together of different things—is an agreeable occupation of the mind : and, beside the present enjoyment, elevates the faculties above low pursuits, purifies and refines the passions, and helps our reason to assuage their violence."

HENRY, 1ST EARL OF BROUGHAM AND VAUX.

" Faced by the mountainous heap of the minutia of knowledge and awed by the watchful severity of his colleagues the modern historian too often takes refuge in learned articles or narrowly specialised dissertations, small fortresses that are easy to defend from attack. His work can be of the highest value ; but it is not an end in itself. I believe that the supreme duty of the historian is to write history, that is to say, to attempt to record in one sweeping sequence the greater events and movements . . . The writer, rash enough to make the attempt should not be criticised for his ambition however much he may deserve censure for the inadequacy of his equipment or the inanity of his results. . . "

STEVEN RUNCIMAN.

CHAPTER SEVEN

Bases of Comparison

FACTORS of performance fall into two broad divisions, one relating to a car as an entity, the other solely with engine design. But overall average speed on a circuit, the fmal criterion of racing car success, is dependent upon four principal factors, which are :

(1) H.P. per square foot of frontal area, which governs maximum speed.

(2) B.H.P. per ton, which determines acceleration.

(3) Braking power expressed over the entire race distance.

(4) Road worthiness.

The first two qualities are easily measurable, and if races were run on tracks with theoretically correct banking and perfect surfaces nothing more would be needed in order to predict the fastest car.

The above statement is, of course, a broad one. It needs modifying in detail to take account of the drag coefficient for a given frontal area ; the weight distribution of the car which determines how much power may usefully be put through the driven wheels ; and the important factor of tractive losses in the tyres concerning which little is known. Generally speaking, however, maximum speed follows very closely upon a cube root law, so that to raise the maximum speed by 10 per cent it is necessary to raise the power per square foot of frontal area by 33 per cent.

In theory such a rule could be substantially modified by changes in body form that affected the drag coefficient ; in practice this has not yet (1953) been so. Designers have found that the use of a really good aerodynamic form involves disadvantages such as greater weight, impaired cooling of the tyres (and greater difficulty of changing wheels) and, above all, inherent instability as the centre of wind pressure moves steadily forward until it is far forward of the centre of oscillation ; in fact, at high speeds the centre of pressure may be well ahead of the nose of the car ! These facts delayed the streamline form from Grand Prix racing on road circuits until 1954, and although the body shape of a 1953 Grand Prix car had lower wind resistance in itself than the hull of a 1914 type, this no more than offset the increased drag of the very large section tyres used on the later, and far faster, cars.

The power lost in driving the tyres themselves is, as has been said before, a subject about which little is known, but there are reasons for believing that at really high speeds it varies as between the square and the cube of the road speed and the frontal area and wind drag of the tyres is very large. In sum, application of the cube root law to the power per square foot of frontal area, gives a reasonable picture of maximum speed potentialities.

Power per ton is another clearly definable quantity which has to be interpreted through two aspects ; firstly, the net weight carried by the driven wheels, and secondly, that the power may be more than sufficient to spin them. In the former case

we are fortunately not required to encounter any major variations. Probably the smallest proportion of weight placed on the rear wheels (and on all the examples considered, these are the driving members) was, say, 50 per cent, and the maximum 60 per cent. We shall not be far wrong to take a figure of 60 per cent up to 1934 and 55 per cent thereafter as normal practice.

Relating h.p. per ton to wheel spin is a more subtle affair, but the following figures will not be found wide of the mark :

B.H.P. per Ton	*Maximum Wheel Spin Speed*
100	50 m.p.h.
200	80 m.p.h.
400	150m.p.h.

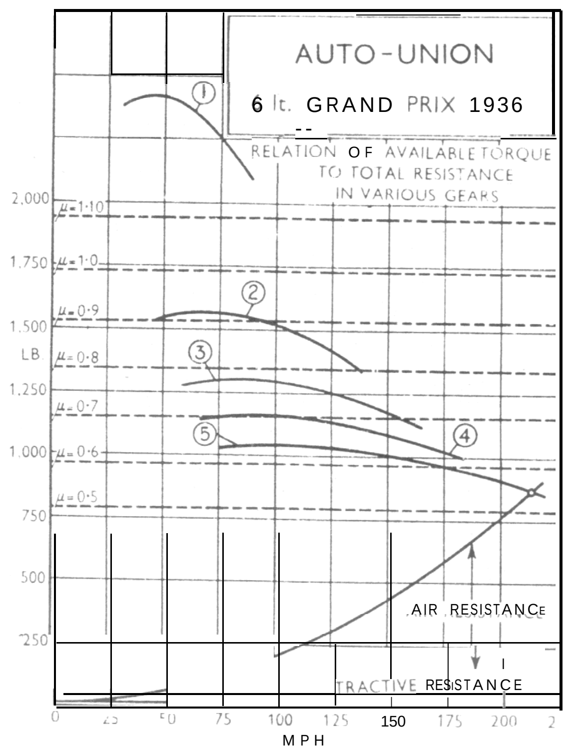
The higher figure presupposes the use of a limited slip differential, the lower presumes an ordinary type. It will be apparent that in the higher powers variations in h.p. per ton figures do not give a direct guide to acceleration, since only part of the power available can usefully be employed. The relative influence of power : weight and the number of driving wheels on acceleration over a standing kilometre have been dealt with in some detail by Eberan von Eberhorst in his Paper, " Hochsleistung im Rennwagenbau " in the *ATZ,* Vol. XI, 1939. He says therein :

> " Calculations of the effect of weight and air resistance upon acceleration have to allow for the fact that (1) average figures produce serious errors ; (2) the maximum output of any engine cannot be represented by a simple mathematical function ; (3) possibility of integration is questionable. However, from the known total resistance curve and the maximum engine h.p. curve it is possible to determine the surplus forces available for acceleration on each gear with a known speed and rear wheel radius. The reciprocal values for acceleration can thus be determined allowing for both the translatory and rotating mass.
>
> In starting the surplus forces will be greater than the tractive limit on the driving wheels and acceleration will be determined by the weight on the rear wheels x the coefficient of friction, minus air resistance and tractive losses. The process of acceleration can be viewed in three phases. First, at the limit of the wheel slip, second, according to the surplus h.p. curves in the individual gears, thirdly, after the surplus forces fall to zero when constant speed is reached.
>
> Knowing the above factors speed can be obtained as a function of time, and by further integration a space-time curve can be derived.
>
> In the case of the Grand Prix Auto Union car of 1937 it was possible to check the actual results obtained over a standing kilometre with those theoretically calculated with various alternative designs. The Auto Union car holds the world's speed record over this distance, but the theoretical speed remains somewhat better if one assumes that there is no gear changing required and that the coefficient of friction could be raised to 1.1. Nevertheless, even with an infinitely variable gear the time required is shortened from only 18.4 secs. (actually realised) to 18.31 secs., and if the lower efficiency of such a gear be taken into account the mean speed would actually be reduced by 3½ m.p.h.
>
> Theoretically, the extra weight of a streamlined car should reduce the speed by 0.94 m.p.h. (and this was confirmed in record attempts on the Frankfurt-Darmstadt Road), but if the reduced drag could be obtained without extra weight there is the theoretical possibility of increasing the average speed by 3.76 m.p.h.
>
> It is interesting to note that four-wheel drive would reduce the time required to cover a standing kilometre by only one second if no weight penalty were incurred, but as this is hardly possible, and making reasonable allowances for the extra weight of this method of transmission, it would offer no improvement over rear-wheel drive.
>
> One concludes that for Grand Prix racing a normal four- or five-speed box with rear-wheel drive and the lowest possible weight represents the best combination. The overriding importance of weight is shown by the fact that if it were possible to halve the existing weight the s.s. Km. speed with four-wheel drive would increase by 25 per cent, or with rear drive and full streamlining by 24 per cent. It must, however, be remembered that such gains only take effect over at most half the length of an ordinary racing circuit, as the braking times would be increased and the maximum speed remain unchanged."

In another paper " Rennformel und Zukunft," published in the *Automobiltechnischen Gesellschaft,* Eberan reproduces some curves relating engine power and average speed on a number of circuits. Taking an average of fast and slow circuits and correlating them with other statistics, one concludes that average speeds rise as the square root of maximum speeds and as shown in the preceding Chapter the evidence of racing over fifty years confirms this.

As maxima vary with the cube root of h.p. per square foot it is evident that average speeds should rise with the sixth root of engine power, e.g. a 5 per cent gain in circuit speed demands a 34 per cent increase in power per square foot. Obviously, such a formula is empiric. It could not remain valid if increases in power were not matched with improvements in braking and road holding ; improvements in chassis design can in themselves lead to gains in speed with no increase in engine output ; and the formula is necessarily limited to the type and size of car used in Grand Prix racing.

The differences in average speed, which might, on theoretical grounds, derive from changes in various aspects of design, have been calculated by von Eberhorst in an article appearing in the fourth issue of Volume I of " Auto Course ". He shows here that an increase in engine performance by 10 per cent, from 390 to 430 b.h.p. would increase lap speed at Monza by 0.53 per cent, but at Silverstone by only 0.16 per cent, although on a sixth root basis the expected figure would be 1.56 per cent. On both circuits a greater gain could be attained by a 10 per cent improvement in braking ; from 0.5 g. to 0.55 g. This would raise the Monza lap speed by 0.56 per cent and the benefit at Silverstone would be 0.60 per cent. Finally, improvement in engine power or braking, of this order, and even the two together, are of far less value than an increase in cornering speed, arising from putting the limit of lateral acceleration up by 10 per cent, from 0.6 g. to 0.66 g. This would give a gain in speed of 2.67 per cent



UNUSUAL ANALYSIS.-This graph has been specially prepared by Prof. Dr. Eberan von Eberhorst to show the surplus horse-power available on all five speeds on the 1936 Grand Prix car, using a top gear giving 210 m.p.h. at 5,000 r.p.m. The gear uiually employed gave 175 m.p.h. at this speed, but even on the higher ratio it will be noted that the wheelspin can be provoked below 100 m.p.h. on first and second gears on dry roads and at up to 175 m.p.h. on all gears with a wet road having a coefficient of friction of 0.6

at Monza, and 3.41 per cent at Silverstone. These figures explain how, at certain periods in racing car history, when special attention has been paid to braking systems and road worthiness, substantial gains in lap speed have been attained with little increase in engine power, or even, in some cases, in the face of a sensible debasement of engine power. But with a few notable exceptions, the relationship proves historically correct with an astonishing degree of accuracy and is a most useful guide to the general progress of design, provided it is used as a guide, and not as an infallible rule.

The influence of braking on average speeds is most difficult to assess. The exact proportion of a race during which the brakes are used will vary with the course, but a figure of 30 per cent of the time, that is to say, one hour total, may be considered typical on the fastest type of car. The rate of deceleration, particularly from the higher speeds, is not so high as might be supposed, and it is doubtful if 0.5 g. would normally be reached with 0.25 to 0.33 g. as more normal figures. One of the most important features of braking is stability of performance over a long period of time and there is no doubt that average speeds were raised not only by the introduction of four-wheel brakes (used by four constructors in the 1914 Grand Prix and universally from 1921 onwards), but also by the very much improved friction linings introduced *circa* 1930, by the re-introduction of hydraulically operated brakes in 1934 and multiple leading shoes from 1936 onwards.

To estimate the statistical effect of road worthiness is impossible, but as this technical narrative unfolds it will be seen that at certain times, and with certain models, the gain in average speeds is more than can be accounted for by any reasonable evaluation of the first of the three factors above set out and must, therefore, spring from the fourth.

No allowance is made for " super tuning " or super driving, although there have been occasional men who have had the reputation of being wizards of tune and able to make their individual motor-car lap far faster than any other example of the type. It can be fairly stated that in every case the design concerned was one which had not been fully developed by the experimental department of the manufacturers concerned. With Grand Prix cars this circumstance rarely, if ever, applied and one can think of hardly any instance where the circuit speed of one *car* in a team has been very greatly different to that of another.

There are very marked variations in average speeds secured by differing drivers, and some have been mentioned in Volume I. It follows that if one team of cars secured all the best drivers the relative performance of the design would be unfairly exaggerated, so from a technical point of view it is fortunate that this has never happened. One ace driver has often put up much better performances than his team-mates, but this has usually been balanced by equally " abnormal " performances on the part of stars driving rival designs.

It may be said that of only two drivers certainly, and less than six possibly, that their personal skill was sufficient to counterbalance a deficiency in engine or chassis design.

When we turn from comparing cars as a whole to power units in particular, we find it necessary to choose the bases of our comparisons with particular care, so as not to fall into errors from which false conclusions could be drawn. In particular it is necessary to demolish the value of h.p. per litre as a means of evaluating engine design.

We can calculate b.h.p. if we know all the quantities involved by using the classic formula $\frac{P \times L \times A \times N}{33{,}000}$ in which

P = the brake mean effective pressure in lbs. per square inch ;
L = the length of stroke in feet ;
A = the aggregate area of the pistons in square inches ;
N = the number of power strokes per minute.

The history of engine development is compounded of all four elements above mentioned. The value of P is determined by the weight of mixture which passes through the valves during the inlet cycle ; the pressure to which it is raised during the compression cycle and the efficiency with which it is burned through the power stroke.

The factors L and N are of particular interest in that they are virtually interchangeable. Piston speed, the product of L x N, is a fundamental limiting factor in engine design and no one has succeeded in producing an engine of any type which will run efficiently and reliably at much over 4,000 ft. per minute. It follows that if L is 152 mm. (i.e. 6 in. or ½ ft.), then for every revolution, the piston will travel 1 ft., so that 4,000 f.p.m. is equivalent to a maximum of 4,000 r.p.m. By reducing the stroke to 76 mm. (or 3 in.), it will be possible to raise the crankshaft speed to 8,000 r.p.m. without exceeding the previous limit of piston speed, since the product of L and N is unchanged, Hence if P and A remain equally unvaried the output will remain the same. In the second case, however, the swept volume of the cylinders (the product of A x L) has been halved and the power per litre doubled.

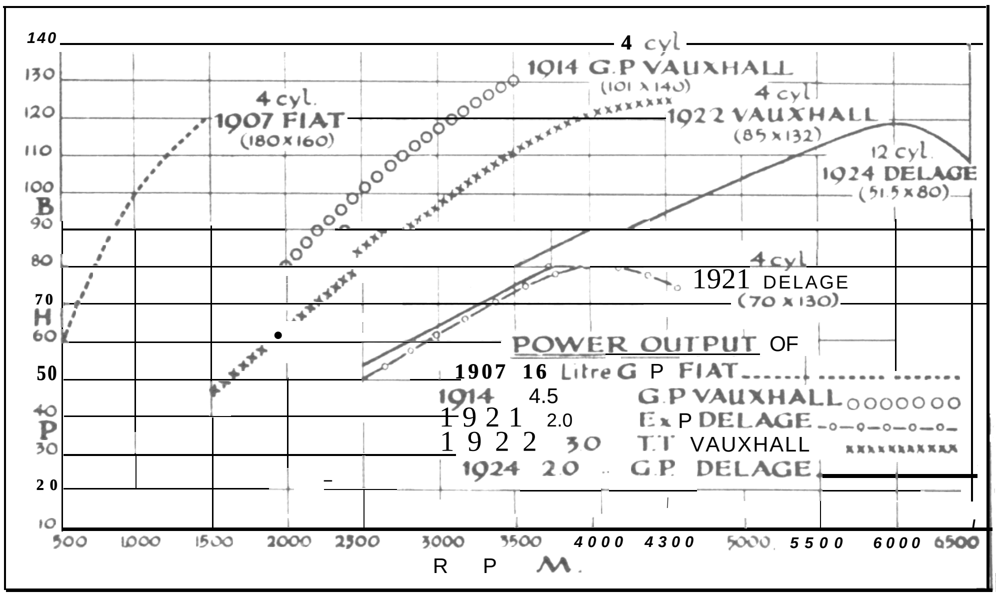
This, admittedly extreme, example discloses the inherent fallacy of comparing engines on a power per litre basis; but it must be admitted that the use of this value is deeply ingrained as a consequence of the use of swept volume in Grand Prix racing formula: and in record breaking. A capacity limit was first imposed in the 1907 Kaiser Prize Race (when it was 8 litres), and this was followed by a 3-litre limit for the popular Coupe de l'Auto Races of 1911, 1912 and 1913, and of 4½ litres for the French Grand Prix of 1914. A 3-litre capacity limit was in force in Grand Prix racing in 1920-l and 1938-9, 2 litres was the limit in 1922, 1923, 1924 and 1925, and l½ litres in 1926 and 1927.

In the post-war period Formula I stipulated 1½ litres (S.) or 4½ litres (U.S.) and Formula II 0.5 litres (S.) and 2 litres (U.S.). In these years power per litre had an absolute significance and has thus acquired a very respectable ancestry. Indeed, so long as the engine volume lay between 2 and 3 litres it formed a convenient and not grossly misleading factor with which to test the merits of a design. The compass of this book, however, extends over much larger variations, from engines having piston strokes of 185 mm. and a capacity of 18 litres down to types having a stroke of 76 mm. and a capacity of 1½ litres, and to make a fair comparison in so wide a field it is imperative that we should abstain from relating power to swept volume and pay regard to the fundamental formula expressed above. In other words, we must concern ourselves, not with crankshaft revolutions and cylinder capacity, but with piston area and piston speed and brake mean effective pressure. This will lead us from h.p. curves expressed against crankshaft revolutions to curves of b.m.e.p. (or of h.p. per square inch of piston area) against piston speed. These are convenient and absolute standards and it is interesting to compare the output curves of five unsupercharged engines of widely different type and age as an example.

As tabulated the figures are :

Date	Car	Capacity Litres	B.H.P.	B. H. P./Litre
1907	4-cylinder (180 x 160) Fiat	16	120	7.4
1914	4-cylinder (101 x 140) Vauxhall . .	4½	130	29
1921	4-cylinder (70 x 130) Delage . . (1922 Prototype)	2	80	40
1922	4-cylinder (85 x 132) Vauxhall . .	3	125	41.7
1924	12-cylinder (51.5 x 80) Delage . .	2	120	60

The h.p. curves of these engines set out in a graph show great dissimilarity, but when re-drawn on a basis of piston speed related to either b.m.e.p. or h.p. per sq. in. all the 1921-4 examples stand remarkably close together. It is particularly interesting to compare the two Delage engines having equal capacity but four and twelve cylinders respectively, as on a power per litre basis the twelve-cylinder engine is 50 per cent better than the four-cylinder design. The other curves reveal, however, that at 3,500 f.p.m. the 1921 engine develops 125 b.m.e.p., which is better by 15 lb. than the 110 b.m.e.p. of the 1924 model. The older type is also superior on a basis of h.p. per sq. in. of piston area. In other words, the 50 per cent gain in h.p. per litre was derived entirely by an increase in cylinder number and piston area, and in the face of a definite inferiority in detail design.



From the foregoing it will be apparent that under any capacity rating the designer who chooses the largest piston area, the shortest stroke, and the highest r.p.m., has secured a fundamental advantage. This notwithstanding, history is replete with examples of successful racing cars having few cylinders, limited piston area, long stroke and low r.p.m.

This apparent contradiction between theory and practice is explained by the fact that working within the framework of existing bearing surfaces, valve gear stresses,

and materials, crankshaft speeds have often been limited irrespective of piston speed. The stressing of bearings, for example, is computed on a Pressure x Velocity factor, and in 1923 Sir Harry Ricardo wrote : " If a continuous mean speed of over 4,000 r.p.m. is to be maintained some form of crankpin bearing other than a plain, white-metal lining will have to be employed."

In 1912 Henri set a fashion for G.P. engines with big stroke : bore ratios, and by so doing produced tall power units which tended to have rather poor rigidity and demanded high bonnet lines. They gained by having small diameter (and easily cooled) pistons and valves, and compact combustion chambers which gave good burning of the charge but as, from 1923 onwards, the problems of revolutions in themselves were gradually overcome, piston strokes were steadily shortened, either by reduced stroke: bore ratios or, as an alternative, by an increase in the number of cylinders. Both of these developments are studied in detail in later chapters.

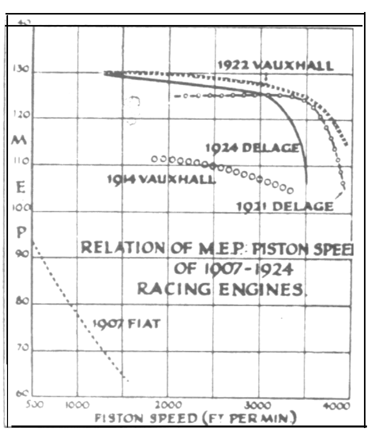
A study of valve area and power per square inch thereof is also germane to our line of technical enquiry. Power output is finally dependent upon weight of air efficiently burnt per minute, and this in the end is fixed absolutely by the breathing power of the valve gear. In detail the gas flow will depend upon the area of the valves, the lift, and the time during which they are open.

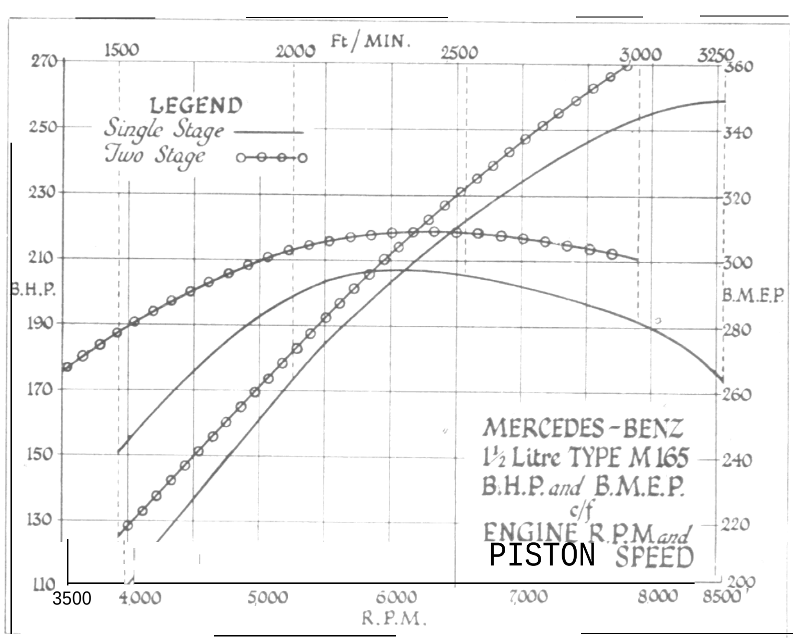
Throughout the examples area has been calculated on the basis of the overall diameter of the valve and the actual throat of the valve seat through which the gas flows will normally be 10 per cent less.

The importance of the valve timing diagram must not be overlooked, for the overall factor of importance is square inch degrees ; that is to say mean effective area multiplied by time per minute during which the valve is opened..

The shape of the ports and their relation one to another exercise an important influence on volumetric efficiency, and it will be seen that some engines have an appreciably higher flow value per square inch of area than others.

These curves are the counterpart of the data given on the previous page but expressed in absolute units.





Curves for b.m.e.p. and piston speed can be combined with the better known comparison of b.h.p. and r.p.m. This example is taken from a 1939 Mercedes-Benz engine.

Artificially raising the inlet manifold pressure is an obviously simple way of avoiding a restriction on capacity based on the swept volume of the cylinders. In effect, by raising the absolute pressure in the manifold from 1 Atm. to 1.5 Atm., designers were able, in 1923-4, to use 3-litre engines whilst keeping inside the 2-litre capacity limit. From this point onwards, therefore, judgment on engine statistics has to be clarified by some knowledge of the supercharge pressure employed.

For the first twelve years (1924-36) in the history of the supercharged engine we can make a reasonable comparison between the unblown and the blown type by reducing all the figures obtained on the latter in proportion to the absolute manifold pressure. If, for example, we observe an engine giving 180 b.m.e.p. and 5 b.h.p. per sq. in. of piston area, with an absolute induction pressure of 1.5 Atm., we can say that it is the equivalent, from a design viewpoint, of an unsupercharged type with an output of 3.3. b.h.p. per sq. in. of piston area and 120 b.m.e.p.

From 1937 onwards such comparisons are vitiated by the increasingly large amounts of power absorbed in driving superchargers designed to produce manifold pressures of up to 2.5 Atm. For example, the supercharger on a 1924 2-litre car, with a pressure rise of 7.5 lb. per sq. in., would require about 20 b.h.p. compared to a net figure of 170 b.h.p. from the flywheel. The 1938 3-litre cars with a boost of 20 lb. per sq. in. required over 150 b.h.p. for the blowers compared with 450 b.h.p. realised on the crankshaft. In other words, the early type can be considered as a 190 h.p. engine less 10 per cent for the blower ; the latter type must be pictured as a 600 b.h.p. engine minus 25 per cent for the blowers.

These sacrifices notwithstanding, the supercharger became an integral part of engine design even when cylinder capacity was unlimited. The supercharged engine was in all circumstances able to show a superior power : weight ratio and, in addition, the mechanical mixing imparted to the ingoing charge eased many fuel distribution problems.

The entire development of the supercharged engine was closely coupled with changes in fuel. Although a major race (A.V.U.S.) was won by a car using a mixture of Petrol, Benzol and Tetra-Ethyl-Lead as late as 1934, from 1924 onwards racing car engines were normally run on fuels having a high content of alcohol. This gave improved anti-detonation characteristics and, far more important, lowered the temperature of the ingoing charge by reason of the high latent heat of vaporisation. On the other hand the lower calorific value of the alcohol resulted in much higher rates of fuel consumption. The quantitive effects are examined in a later chapter, but it is important to recognise that one cannot fairly compare an engine running on petrol with a 6 : 1 compression ratio and atmospheric induction pressure with one running on alcohol and using a 7 : 1 compression ratio with a manifold pressure of 1.7 Atm. It will, incidentally, be convenient to distinguish between boost pressure above the normal atmospheric and absolute manifold pressures by using a German convention of “ Atu ” for the former and “ Ata ” for the latter ; e.g. 15 lb. boost is 1 Atu but 2 Ata.

CHAPTER EIGHT

Ancient to Modern

UP to the 1914 war the Grand Prix of the Automobile Club de France stood by itself as an event of international importance. No races were organised by the Club for the years 1909, ‘10 and ‘11, so that there were only six events in the nine effective racing years. These, both technically and chronologically, may be conveniently divided into three pairs.

The first two races may be considered as virtually a continuation of the Gordon Bennett type of car ; the last two, 1913 and 1914, saw the embodiment of all the mechanical features (except superchargers and independent suspension) which have been used from that day onwards ; the races of 1908 and 1912 formed the bridge between the two movements.

In the 1906 and 1907 Grand Prix events all the effective competitors had four-cylinder engines with exceedingly large swept volumes judged by modern standards. The biggest power units had 18.3 litres in 1906 and 19.6 litres in 1907, the winning cars having engines of 13 and 16.3 litres. Moreover, apart altogether from variations in design with different makes, many of the leading competitors ran Grand Prix cars almost, if not completely, identical with their immediate predecessors. The Richard-Brasier, for example, which had won the 1905 Gordon Bennett Race, was continued almost unaltered for the first two Grands Prix, and it made the fastest lap in 1906. The broad specification of the 1907 winner was also scarcely changed from the 1905 design, although output had been increased by.approximately 10 h.p.

The dawn of the present age began in 1908, in which year the regulations limited the piston area so that the maximum bore for a four-cylinder engine was 155 mm. This forced designers to construct entirely new engines, and at once we see two marked developments from previous practice. Some constructors sought power by increasing engine r.p.m. and piston speed, others by developing brake mean effective pressure. The Itala (Example No. 1) followed the former trend ; the winning Mercedes design typifies the latter. It is significant to make a technical comparison between these two 1908 cars, the Richard-Brasier, which had been so successful in 1905. and 1906, and the winning Fiat of 1907.

ENGINE DEVELOPMENT 1905 TO 1908

Make	*Year*	*No. of cyls.*	*Cyl. dimensions* ***m/m***	*Cyl. capacity Litres*	*B.H.P.*	*R.P.M.*	*Ft./ Min.*	*M.E.P.*	*H.P. Litre*	*H.P.sq ins.*
R. Brasier	1905	4	160 x 140	11.3	101	1,350	1,240	86.5	9.1	0.84
Fiat	1907	4	180 x 160	16.3	130	1,600	1,680	65	8.05	0.82
Mercedes	1908	4	155 x 170	12.8	135	1,400	1,570	96.5	10.4	1.15
Itala	1908	4	155 x 160	12.05	100	1,600	1,700	67	8.3	0.85

The crank and piston speed of the Itala may be considered exceptional, but it is interesting to note that during the first three Grand Prix events, designers maintained very short stroke : bore ratios, the figures for the winning cars being :

$$\left.\begin{array}{ll} 1906 \quad . \quad . \quad . \quad . & 0.90 \\ 1907 \quad . \quad . \quad . \quad . & 0.89 \\ 1908 \quad . \quad . \quad . \quad . & 1.10 \end{array}\right\} : 1$$

Average .. .. 0.98 : 1

Improvements in detail design are plainly apparent in the gains in b.m.e.p. and h.p. per sq. in. of piston area realised in the Mercedes design. This was achieved without any basic changes in materials or layout, for at this stage in automobile development there was still much to be done in the way of minor refinements of cam form, induction pipe design and valve settings.

Transmission, frame, and suspension lay out showed little change, although there was a steady trend towards displacement of chains by live axles. Shock absorbers, which had been introduced by Mors in 1899, were now universally employed and this, in conjunction with light axles (the front beams being unembarrassed by the weight of brake mechanisms), permitted relatively soft suspension and excellent handling characteristics, thereby contradicting the high and comparatively unstable appearance of the cars.

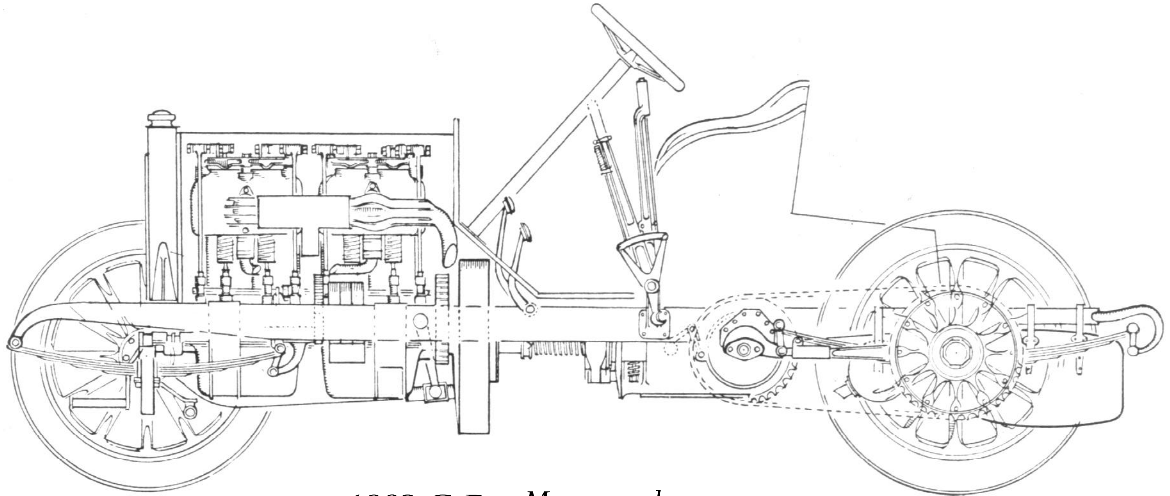
The height was neither a whim nor a fashion retained without reason. A drawing of the 1908 winning car shows that the 21½ in. diameter flywheel was given a clearance of 6½ in. from the ground, and this brought the centre line of the crankshaft approximately 17 in. from the ground. With a 170 mm. stroke and allowance for overhead valve gear the top of the engine becomes 48 in., and the highest point of the bonnet 50 in., above the ground.

The driving position was built up in the following fashion. The rear wheel diameter was 35 in., making the centre line of the rear axle 17½ in. from the ground. The bottom of the frame was on the centre line of the rear axle and the chassis members were 5.1 in. deep, and the seat came 8 in. from the floor boards, so we get a final height from the ground to the seat cushion of 31½ in. This brings a normal driver's head rather over 5 ft. from ground level.

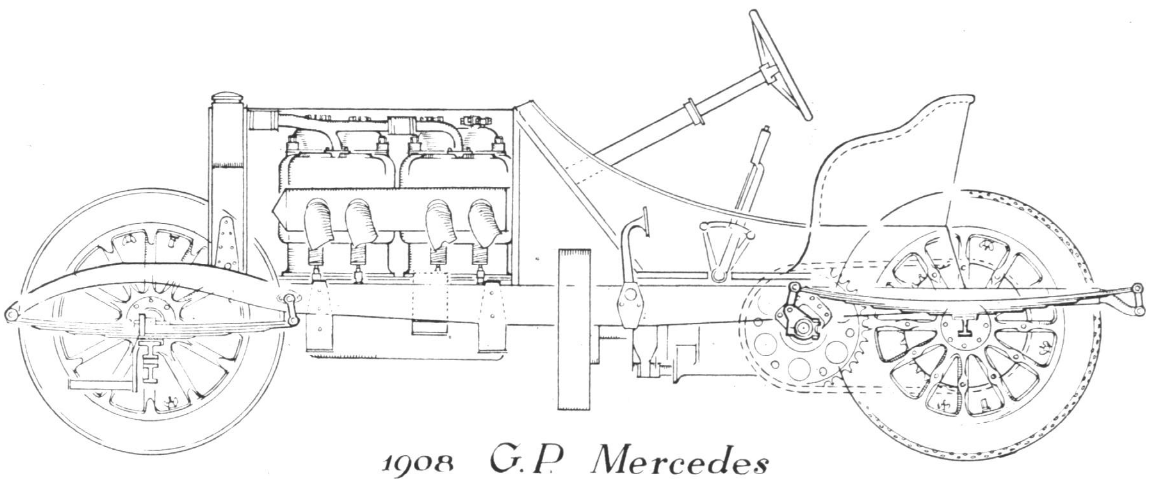
It will be seen from the foregoing statistics that although these cars had a high centre of gravity they also had a high roll centre and the 1908 models generally had an extremely effective performance on the road and were far faster than the 1906 and 1907 models.

The 1908 Grand Prix cars can be regarded as signposts of what was to come. The winner of the 1912 Grand Prix was the seed from which modern racing cars have sprung. The event, one of intense technical interest, was run over the Dieppe Circuit used in 1907 and 1908, and it is, therefore, possible to make definite speed comparisons despite the lapse of three years.

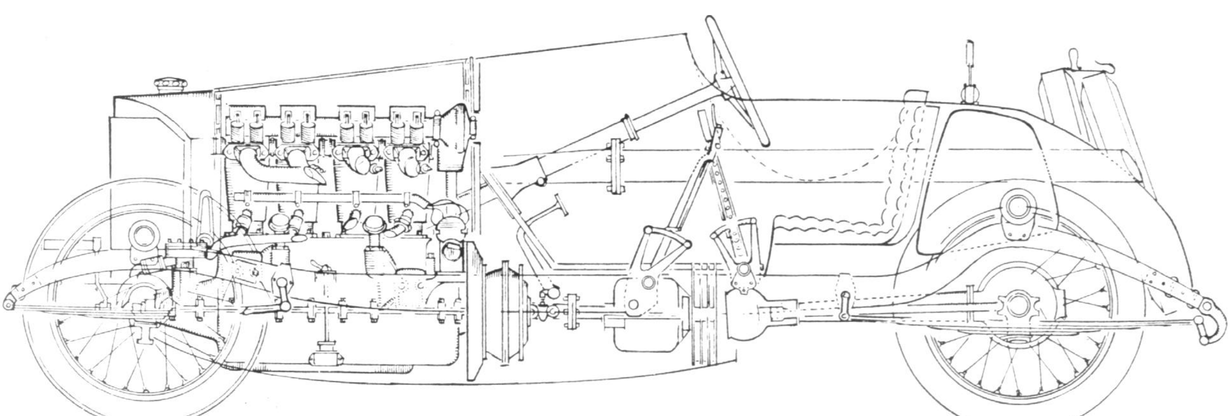
Designers had a free hand in the matter of engine size and type of car, and the race resolved into a struggle between a continuation of the 1908 type of car run by Fiat and a new concept sponsored by Peugeot. The former car was powered with an engine of four cylinders, 150 x 200 mm., giving it a capacity of 14 litres. The four over-



1903 G.P. Mercedes

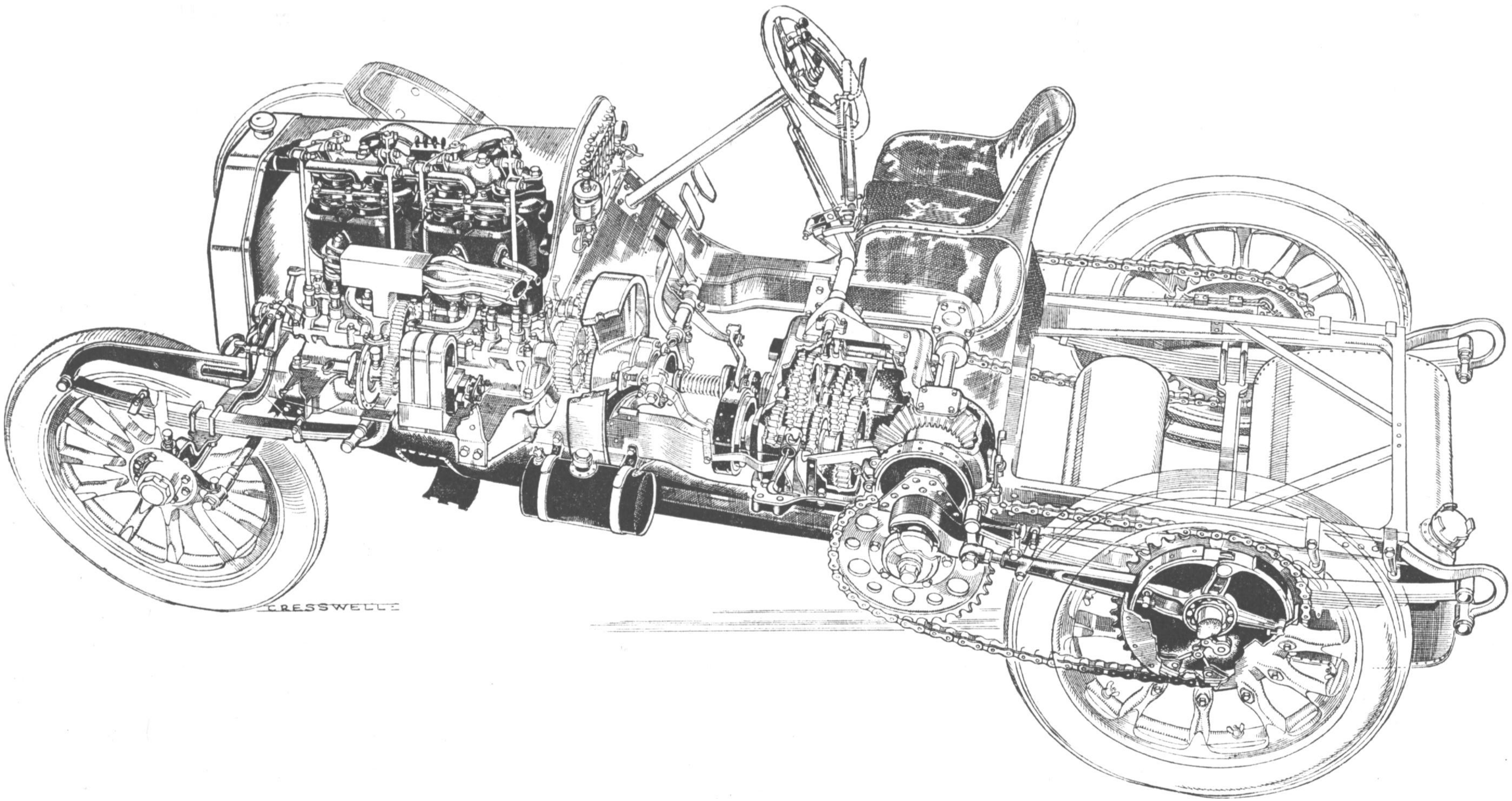


1908 G.P. Mercedes



1914 G.P. Mercedes

Winning Mercedes racing cars, 1903-1914. Scale 1 : 25



The 60 h-p. Mercedes–winner of the 1903 Gordon Bennett Race

head valves per cylinder were operated by an overhead camshaft and chain drive was used to transmit the power to the fixed wooden wheels with detachable rims. These cars proved to be the fastest on the circuit, and if they had not been put out of the running by entirely petty troubles would most certainly have won. Victory was secured, fortunately perhaps, by the more technically interesting design of Peugeot. This car used a four-cylinder engine, 110 mm. by 200 mm. (7.6 litres capacity) and it should be immediately apparent that it represented a complete departure in the matter of stroke : bore ratio from the practice of 1906-8.

The source of this change may be found in the Lion-Peugeot entries in the voiturette racing of 1909 and 1910, voitures légères of 1911, and in particular those events sponsored by the French paper *l'Auto* . From 1906 onwards the engines used in the annual competition for the cup put up by this enterprising journal were limited in the following way :

1906-Single-cylinder engines maximum bore 120 mm., two-cylinder engines maximum bore 90 mm., minimum weight 700 kg.

1907-Single-cylinder engines maximum bore 100 mm., maximum weight 670 kg., two-cylinder engines maximum bore 80 mm., maximum weight 850 kg.

1908-Single-cylinder engines maximum bore 100 mm., two-cylinder engines maximum bore 80 mm., four-cylinder engines maximum bore 65 mm., with minimum weights of 500, 600 and 650 kg. respectively.

1909-Single-cylinder engines 100 x 250 mm. up to 120 x 124 mm., two-cylinder engines 80 x 192 mm. up to 95 x 98 mm., four-cylinder engines 65 x 150 mm. to 75 x 75 mm.

1910-Single cylinder, maximum bore 100 mm., maximum stroke 300 mm. = 2.35 litres capacity ; two-cylinder, maximum bore 80 mm., maximum stroke 280 mm. = 2.8 litres ; four-cylinder, maximum bore, 65 mm., maximum stroke 260 mm. = 3.45 litres, minimum weight, 650 kg.

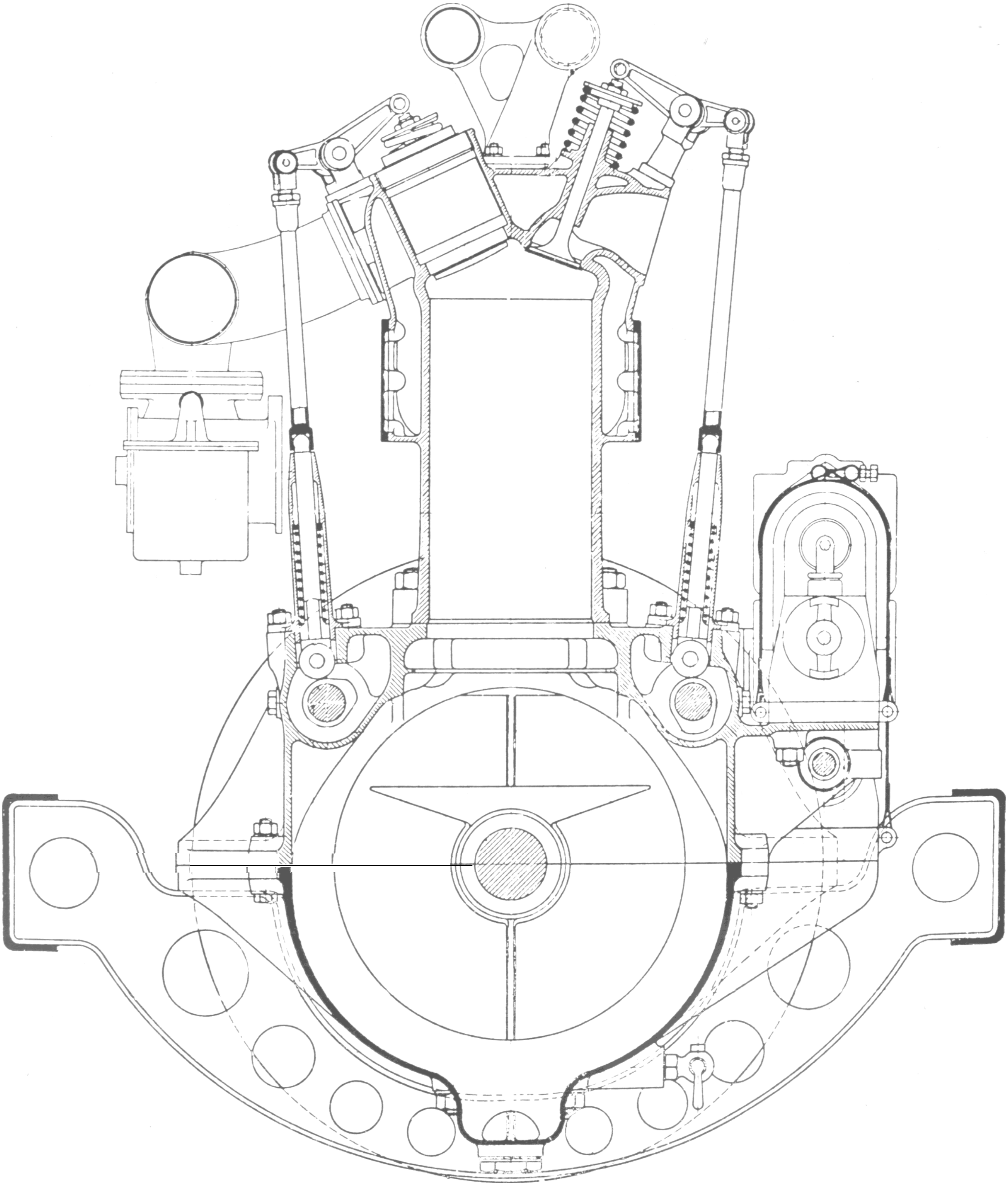
191l-Maximum engine capacity 3-litres with S : B ratio not exceeding 2 : 1 or under 1 : 1.

1912-As 1911, minimum weight 800 kg.

1913-AS 1912, but maximum weight 900 kg. and superchargers barred.

As can be seen from a discussion of these events in the first section of the book, the result of these regulations was to foster cars with extreme S : B ratios and although the Lion-Peugeot cars were specifically the winners of the Coupe de 1'Auto in 1909 only, they put up the fastest lap not only in that year but also in the two subsequent years. The automobile side of the Peugeot family enterprises was divided into two parts. Large cars were built in Paris whereas cycles, motor cycles and small cars, sold under the name of Lion-Peugeot, were constructed near Belfort. It is from this last-named concern that the Coupe de 1'Auto cars emanated. The chassis of the models with semi-elliptic springs and chain drive was not particularly remarkable, but the engines showed great ingenuity.

Although in 1907 the limited cylinder bore of 100 mm. was used in conjunction with the then-orthodox S : B ratio of 1.2 : 1 from 1908 onwards the designer, M. Michaux, wholeheartedly joined, if indeed he did not lead, the trend towards quite abnormal stroke : bore ratios. One might have thought it logical to use piston strokes



The 1910, 7.3 litre, Prince Henry Benz engine. Scale 1 : 4.

already established in the realm of Grand Prix racing, even when the cylinder bores were limited by regulation, and there would thus have been nothing surprising in the use of strokes of up to 190 mm. (for this dimension was used on the 1899 Peugeot and the 1901 Mors) and strokes measuring between 170 and 180 mm. were commonplace for the 1906-1908 Grand Prix cars. But figures of this order were quickly exceeded by the small cars and it is of interest to take some typical instances using the same criteria employed in the table of typical 1905-8 models set out on an earlier page.

LIGHT CAR ENGINE DEVELOPMENT 1908 TO 1911

Make	*Year*	*Cyls.*	*Dimensions*	*Piston area sq. in.*	*Cyl. capacity*	*b.h.p.*	*r.p.m.*	*ft/min.*	*b.m. e.p.*	*h.p./ litre*	*h.p./ sq. in*
Sizaire-Naudin . .	1908	1	100 x 250	12.2	1.96	25	2,400	3,937	79.3	12.8	2.07
Peugeot	1909	1	100 x 250	12.2	1.96	30	2,200	3,620	90	15.4	2.46
Brooklands Vauxhall	1909	4	90 x 118	39.4	2.99	45	2,250	1,775	86.5	15.0	1.14
Peugeot . . .	1910	2	80 x 280	15.6	2.80	40	2,200	4,042	85	14.2	2.55
Hispano-Suiza	1910	4	65 x 200	20.05	2.65	45	2,500	3,300	88.5	17.0	2.2
Brooklands Vauxhall	1910	4	90 x 118	39.4	2.99	60	2,750	2,170	101.0	20.0	1.53
Delage	1911	4	80 x 149	31.1	2.99	50	2,500	2,440	86.2	16.7	1.77

The h.p. figures given for the 1908 Sizaire-Naudin and 1909 and 1910 Peugeot cars are estimates based on their lap speed at Brooklands. The others are derived from various published information although it must be remembered that these races attracted comparatively little attention in the current motoring press and the data contained therein is very scanty. But whether or not the figures are exact for any individual car we can say that those performance factors influenced by crank and piston speed, i.e. h.p./litre and h.p./sq. in., show a tremendous increase in comparison with the Gordon Bennett and Grand Prix cars built in the preceding four years. Figures for b.m.e.p., on the other hand, showed little development ; indeed the designers were taxed to the limit to sustain this quality in the face of increasing speeds and they resorted to a number of expedients in order to retain adequate valve area.

Michaux for Lion-Peugeot showed a partiality for multiple valves and the 1909 single-cylinder car had three inlet and three exhaust valves placed horizontally and opened by a rather complicated system of eccentrics and connecting rods.

The 1910 two-cylinder model had a camshaft mounted vertically in front of the cylinders which opened two horizontal exhaust valves (each 46 mm. diameter) and simultaneously drove through bevels a horizontal camshaft passing between the cylinders which opened a single 62 mm. inlet valve in each cylinder head. Inlet and exhaust valves closed virtually at T.D.C., the inlet closing 39 degrees A.B.C. and the exhaust valves opening 50 degrees B.B.C. The inlet valve thus had a total opening period of some 219 degrees.

It will be seen that the valve area on this engine was 9.35 sq. in., giving 3.8 h.p./ sq. in. of valve area-a figure rather higher than that attained in the Grand Prix cars

of an earlier period. On the Hispano-Suiza also the use of a T-head must have made it possible to employ four inlet valves not less than 55 mm. diameter, that is to say, a total valve area of 14.8 sq. in. and a flow value of 3.85 h.p./sq. in. On the other hand, the use of an L-head on the Vauxhall limited the valve diameter to 45 mm., giving the very high flow factor of 6¼ h.p./sq. in.

On paper the very long stroke engines produced an impressive set of figures ; indeed, as it was not until after 1920 that designers solved the crank and valve-gear problems associated with speeds of over 3,000 r.p.m., the long stroke type had much to recommend it as an engine under piston area regulations. But even as early as 1910 many disadvantages were making themselves felt. Big valve area derived from multiple valves produced complicated core work in the castings, leading to inadequate water passages and inherent overheating and the T-head and the horizontal valve alternatives gave poor shapes of combustion chamber. On the V-twin Peugeot engines in particular the height was such as markedly to reduce the driver's vision and, perhaps even more serious, to raise the centre of gravity to a point where the car could become unstable.

The 1910 regulations definitely encouraged multi-cylinders, the relation between singles, twins and fours- being 1.0, 1.27, and 1.7 on a basis of piston area, and 1.0, 1.2 and 1.48 on swept volume.

A turning point in the development of the Lion-Peugeot cars, and indeed of the racing car as a whole, followed the transfer of Zuccarelli from the Hispano-Suiza to the Lion-Peugeot racing team for 1910. He, like the two other principal drivers, Goux and Boillot, was engineer-trained, and they could all well appreciate the fundamental limitations of the Michaux engines, and indeed of Monsieur Michaux himself. Unlike the majority of racing car drivers, these three had the intellectual power to draw up a specification for a car that would represent a very great technical advance on anything hitherto constructed ; during 1911 they not only sketched out their design on paper but also made some unofficial approaches to various suppliers of components and raw materials. Having safely secured the promise of substantial support, they laid their plans before M. Robert Peugeot, who was so much impressed by the possibility of obtaining a team of racing cars at a cost to himself of only £5,000 that he gave the project his blessing. Moreover, as the A.C.F. were now known to be sponsoring a revived Grand Prix of 1912, the bold decision was made to make the racing department of the Lion-Peugeot Co. responsible for the production of three full-size Grand Prix cars plus a pair of 3-litre models for the ensuing Coupe de 1'Auto.

The three drivers asked Peugeot to engage a young Swiss engineer called Henri to translate their ideas on to the drawing board, and in this way the foundations of subsequent engine development were laid.

The Vee engines of Michaux, which inherited a 16 degree included angle between the bores from the two-cylinder Daimler engines supplied to Peugeot in 1894 and described in the original Daimler patent of 1889 were replaced by in-line engines which retained an S : B ratio of approximately 2.0 : 1, but despite a long stroke the secret of the 1912 Peugeot's performance lay in the recognition that crankshaft speeds would continue to increase and that this would force the development of improved valve gear.

As late as 1909 the technical press ridiculed the notion that engines having a crankshaft speed of 2,000 r.p.m. could safely be sold to the public, but in 1910, the Vauxhall designer, L. H. Pomeroy, when replying at a discussion in the Institution of

Automobile Engineers to his paper " Engine Design for H.P. Rating Rules ", said " There is no doubt that before the end of the next twelve months the engine which cannot develop its maximum h.p., and keep going, at 3,000 r.p.m. will be a back number."

The specific Peugeot contribution towards the fulfilment of this prophecy lay in the use of valve gear which combined a compact combustion chamber with large valve area and low inertia. In 1904 the Belgian Pipe engine was built with inclined valve head and a central sparking plug, the included angle between the valves being 120 degrees. Two valves per cylinder were used worked through rockers and push-rods extending down into the crankcase, a camshaft being mounted on each side of the crankshaft. This same general layout was used in the 1908 Prince Henry Benz engine in which the four valves per cylinder were disposed at an included angle of 60 degrees.

Engines with overhead camshafts were also well known, the Mercedes Co. for example producing a six-cylinder of this type with vertical valves placed in a kind of inverted T-head, whilst the extremely fast 1908 Clement-Bayard used a single o.h.c. in conjunction with two inclined valves per cylinder operated through rockers. The advance made by the Peugeot team was in amalgamating all these anticipations and adding to them virtually direct operation. By using four inclined valves per cylinder with two overhead camshafts they lowered the valve gear stresses and enlarged the valve area.

As so often happens, the farm of their endeavour was not immediately garnered. If, for example, the 1909 single-cylinder engine had been built as an in-line four it would have theoretically resulted in an 8-litre power unit developing not less than 120 h.p. and this would have been but little less than the figure actually realised on the 7.6-litre 1912 model, but as crank speeds of 3,000 r.p.m. changed from prophecy to reality Peugeot received a handsome reward for their pioneer work and all their competitors were forced to follow along the same lines.

The 1912 Grand Prix car as it came from Henri's drawing board was also remarkable for being a balanced whole in which the superiority of, for example, the live axle over chain drive was finally established.

The chassis was notable in the use of detachable wire wheels and Hotchkiss drive. The Rudge Whitworth type " knock-off " wire wheel was invented in 1906 and was suggested as an alternative to the detachable rim type for the 1908 Grand Prix, but was specifically prohibited by the regulations for that event. In the following years this equipment became widely used on touring cars, and there were no objections raised to its employment in the 1912 Grand Prix. Peugeot took advantage of this, whereas, as has been before-mentioned, Fiat adhered to the detachable rim despite which handicap they were able to change a tyre in 40 sec. The Peugeot's live rear axle drove the car through the medium of the rear spring leaves on what is known as the Hotchkiss system. The weight of the torque tube was thereby eliminated, and although it was not realised at the time, rear steering effects were considerably diminished.

The car as a whole was remarkable for the care taken in the detail design, and this has been referred to in Part II, Volume I. As compared with its predecessors it will be seen that the h.p. per ton and per square foot were both subject to a useful improvement, but the timed performances of the car show it as more remarkable for the technical advance in engine layout than, prima facie, for any startling increase in speed.

In the 1913 Indianapolis 500-Mile Race this car realised more than 8 m.p.g. at a winning speed of 75 m.p.h. for the 500 miles, and this was an indication that little change

in the overall design was needed to meet the requirements of the 1913 French Grand Prix which was run on a fuel consumption basis. A minimum of 14.12 m.p.g. was required, and the winning car, driven by Boillot, actually averaged 16 m.p.g. at a road average of 71.65 m.p.h.

The engine was a refined edition of the 1912 type, the stroke/bore ratio being maintained at 1.8 : 1 with absolute dimensions of 100 x 180 mm. giving a swept volume of 5.6 litres for four cylinders.

A specific consumption of 0.6 pt. per b.h.p. hour on the bench and 15 m.p.g. at maximum speed all-up on the road was claimed for these cars. These creditable figures were doubtless due to the great attention paid to the reduction of mechanical friction, including the use of a two-piece crankshaft bolted together through a centre roller bearing. Ball bearings supported the crank at each end and it was claimed that the engine developed maximum power at 2,100 r.p.m. In common with the 1912 type the designer introduced another feature which was intended to reduce friction loss between pistons and cylinders. This was the expedient known as " Désaxé," which was not uncommon at this time. Heirman, in his work, *l'Automobile à Essence, Principes de Construction et Calculs,* published in 1908, refers to an article by M. Louis Lacoin in No. 34 of the French paper *Omnia,* in which it is calculated that by offsetting the cylinder axes by 50 per cent of the crank radius the overall mechanical efficiency is raised from 77.22 per cent to 78.53 per cent ; and Peugeot made a regular practice of offsetting cylinders in this way. Considerable attention was also paid to increasing the rigidity of the engine by improved crankcase design. The 1912 engine had a conventional crankcase split on the centre-line of the five plain crankshaft bearings, but the 1913 type used a barrel-type crankcase, the crankshaft being inserted through the end complete with the centre main bearing.

Principal competition to Peugeot in 1913 came from a Delage, having four horizontal valves per cylinder and 105 x 180 mm. bore and stroke. Delage had also been prominent in the Light Car Races and the use of a stroke : bore ratio of 1.71 : 1 was, therefore, not unexpected. The lessons of Peugeot successes in 1912 were, indeed, widely disseminated by 1913, and the Excelsior entry had a stroke : bore ratio of 1.66 : 1, the Opel 1.76 : 1, and Sunbeam 1.87 : 1.

Even Itala, with their pre-1908 traditions, used a ratio of 1.36 : 1, and Schneider entered with an S : B ratio of 1.9 : 1.

From a technical viewpoint the outstanding car of 1913 was not the Grand Prix, but the 3-litre, Coupe de l'Auto, Peugeot. Reference to the data table shows that compared to the 1912 type both h.p. per litre and h.p. per sq. in. of piston area were nearly doubled and b.m.e.p. raised by one-third. The car was also extraordinarily light, so that despite an engine capacity of only one-quarter that used on the 1908 cars, there was little difference in h.p. per laden ton. The flow value of the valves also reached a remarkably high figure and the overall result was such that the car was not only much ahead of competitors in its own class, but could also successfully compete with the 1912 and 1913 Grand Prix types, in which engine capacity had not been limited (*vide* Chapter 5, and Example No. 4). It may indeed be said that the appearance of the British Sunbeam and Vauxhall cars in the 1912 Grand Prix, and the performance of the 1913 3-litre Peugeot, were definitive factors in the establishment, for the first time, of a capacity limit in Grand Prix racing in 1914.

The extent to which Henri dominated European designers in 1914 was shown by the entrants for the Grand Prix of that year. Of the thirteen makes (four French, three Italian, two German, two English, one Swiss and one Belgian), ten had four overhead valves per cylinder and one three valves per cylinder. Only Fiat with two valves per cylinder and a Piccard-Pictet with a Burt McCollum single-sleeve-valve engine represented alternative schools. All poppet-valve engines had the camshaft above the cylinder, and Delage, Sunbeam, Vauxhall and Nagant, in addition to Peugeot, used double overhead camshafts.

Peugeot practice in the matter of stroke : bore ratio was equally in evidence. Vauxhall and Fiat had the two shortest strokes, with bore and stroke 101 x 140 mm. and 100 x 143 mm. respectively, but the most popular size was 94 x 160, giving a stroke : bore ratio of 1.6 : 1. The stroke : bore ratio for the winning car of 1912-4 is :

1912	. . . .	1.82 : 1
1913	. . . .	1.80: 1
1914	. . . .	1.71 : 1
Average	. . . .	1.78 : 1

We observe a paradox inasmuch as the four-cylinder, 4½-litre engines of 1914 had actually a 15 mm. longer stroke than the 12.85-litre winner of 1906, that is to say, the rules enforced a reduction in capacity of 65 per cent ; the designers voluntarily accepted a corresponding diminution of piston area. But, as in the 1908-12 Light Car engines, designers could not convert speed into r.p.m. to the best advantage. If, for example, a four-cylinder engine had been built with dimensions 108 x 117 (a stroke : bore ratio of 1 : 1.08) the current piston speed of 2,800 f.p.m. would have represented 4,000 r.p.m. and a potential output of 165 b.h.p. or 41 b.h.p. per litre. At this time no successful racing engine had been run at over 3,000 r.p.m. or with an output in excess of 30 b.h.p. per litre, and for both mechanical and thermal reasons it was too much to expect designers to take a step forward amounting to 33 per cent in twelve months.

So far as engines are concerned it may, in fact, be said that the 1914 Grand Prix cars confirmed and consolidated in general the gains which had been made by the 1913 Coupe de l'Auto Peugeot in particular. Delage and the winning Mercedes were of particular interest in that they showed certain definite departures from the general acceptance, of Henri ideas. The former used valves at an included angle of 90 degrees, whereas the more general angle was 60 degrees, with Vauxhall only 18 degrees. Delage used positively closed valves, a scheme which was, however, not marked with success. Mercedes, using aero engine experience, employed a cylinder construction which was to have a marked effect on subsequent design. In the previous two races the use of four cylinders made from one iron casting including the head had become almost universal. The winning Mercedes went to the opposite extreme of having four separate cylinders attached to the crankcase and each one fabricated from a steel forging having one closed end in which the valve seats were bored. The ports were then made from steel sheet and welded on to the barrel, provision being made further for welding the guides into the ports. After this had been done a light steel water jacket was welded over the whole assembly with the addition of suitable connections for water flow between one cylinder and the other, and supports for the overhead camshaft. This construction, retrograde in that the overall stiffness of the engine was lowered by the use of individual cylinders, was markedly progressive in that complete control could

be obtained over metal thickness and water brought very close to all the hot spots in the head with entire freedom from the possibility of the design being marred by errors in casting.

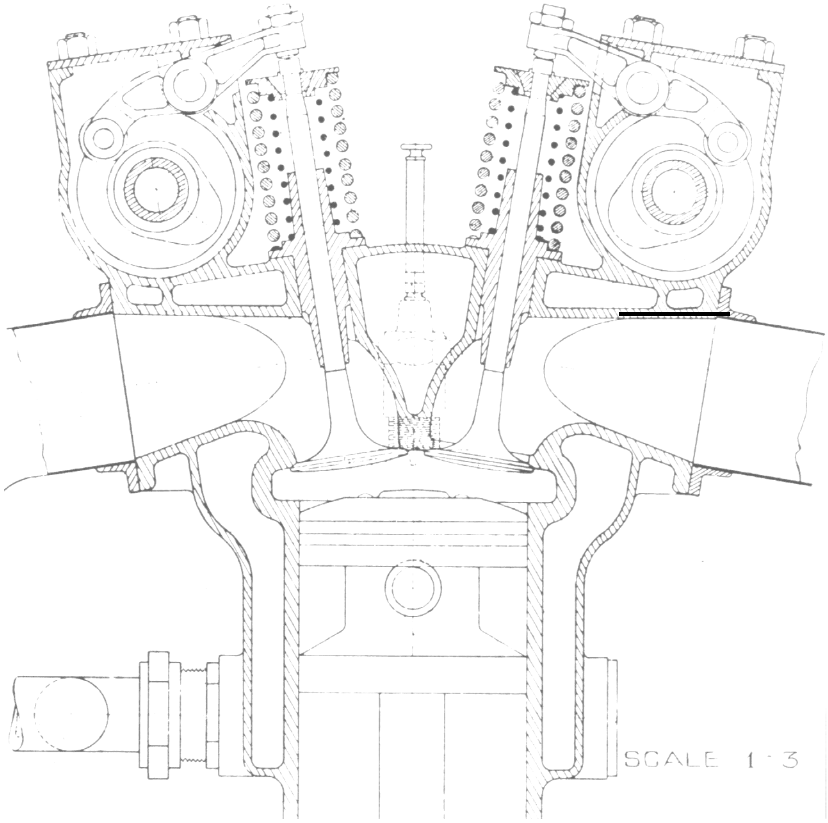
Progress in technique notwithstanding, the limit on engine capacity resulted in a definite reduction in total engine output, and the constructors estimate that the winning engine of 1914 developed 115 h.p., that is to say 25 h.p. less than their victorious model of 1908. Such lower powers were, however, offset by two noticeable changes in the design of the cars themselves. There was firstly a marked reduction in height, despite the fact that engine height remained virtually unchanged. By passing the rear springs beneath the rear axle instead of above it and by using a double drop in the frame, the height of the latter was reduced to 14¾ in. from the ground, and with a slightly lower seat this resulted in the driver’s head coming just under 60 in. from ground level. The scuttle height was also a good deal reduced, leading in all to a reduction in area from between 18 and 19 sq. ft. for the 1908 cars to 13 sq. ft. for the 1914 types. This change is of greater magnitude than the reduction in h.p., so that we can put the power per sq. ft. of frontal area as follows :

1908 Mercedes 7.7 h.p. per sq. ft.
1914 Mercedes 8.85 h.p. per sq. ft.

The same general considerations apply to other makes.

An outstanding change was effected by a minority of the 1914 designs, and although it did not make the difference between victory and defeat, it transformed an important aspect of racing car design. Hitherto braking systems on racing cars had been restricted to the rear wheels only, although the brakes themselves were placed both adjacent to the rear hubs and on the transmission line. The possibility of braking on all four wheels had been the subject of discussion from a very early stage of design and was realised in practice by a number of cars such as the British Phoenix of 1908 and, more prominently, the Argyll of 1911, and Isotta Fraschini in 1910. In the 1912-13 period Louis Delage had much practical experience of front brakes on touring cars, which proved to him that the objections commonly voiced, that is to say the danger of locking the steering wheels on corners and excessive tyre wear, were not sustained, and that the system could safely be used on his 1914 racing cars. This came to the knowledge of Georges Boillot, who made some tests of the Argyll car with Perrot-type brakes during the London Motor Show of 1913. He made an enthusiastic report to Henri, but at this stage (November) it was too late to incorporate the Perrot system in the Peugeot design. This Company, therefore, adopted an alternative scheme developed by Isotta Fraschini and used by them on their 1910-1l racing cars in the U.S.A.

The principal differences between the two layouts were that in the Perrot system the camshaft for the front brakes was joined to an external shaft running above the front axle, which was pivoted on the frame and used two universal joints. It was thus possible for the axle to rise and fall, and for the wheels to run without disturbing the braking mechanism. In the Isotta system the whole of the shafting was fixed on to the axle and turning of the wheel was accommodated by a floating cam. These systems are illustrated in Example Nos. 6 and 9 respectively. Fiat and Piccard-Pictet also used brakes on all four wheels. Unfortunately, only Peugeot had sufficient power under the bonnet to keep within sight of the rear-braked Mercedes team and hence at a decisive point in the technical history of motor racing we are baffled in our endeavour to discover



The 1914 G.P. Vauxhall engine. Scale I : 3.

the exact value of a revolutionary change. Observers on the course were all agreed that the Peugeot drivers had a very big advantage on corners. For example, speaking of a duel between Lautenschlager and Goux on a Peugeot, one writer says " Both went all out from the bend, tearing down to the village of Sept Chemins like a couple of speed demented monsters. Lautenschlager got there first-and then they were hidden from my view by the cottages. I put my glasses on the return road and it was a Peugeot model which first came into view ; I calculated, therefore, that the front-wheel brakes enabled Goux to catch up in the S-bend in the village." Despite this the Mercedes lap times were uniformly better than those of the Peugeot, and again referring to contemporary observation it was estimated that if the German cars had been front braked their times would have been reduced by 50 and 60 seconds a lap. This, purely a guess, was tantamount to saying that front brakes raised average speeds by 5 per cent without change in engine output.

CHAPTER NINE

The First Decade

STATISTICS OF RACING CARS 1906-1914

	1908 Itala	1910 Fiat	1912 Peugeot	1913 Peugeot	1914 Mercedes
Cylinders	4	4	4	4	4
Bore	155	130	110	78	93
Stroke	160	190	200	156	165
S/B Ratio	1.03	1.42	1.82	2.0	1.77
Cylinder Capacity	3,020	2,521	1,900	735	1,120.8
Engine Capacity	12,080	10,084	7,600	2,981	4,483
B.H.P.	100	120	130	90	115
R.P.M.	1,600	1,650	2,200	2,900	2,800
B.H.P. per Litre	8	10.1	17.1	30	25.6
B.M.E.P. lb./sq. in.	67	78	101	134	120
Piston Speed ft./min.	1,700	2,060	2,880	3,000	3,000
Inlet Valve Area sq. in.	44		28.4	14	21.5
H.P. per sq. in. Inlet Valve Area	2.28	2 %	4.58	6.43	5.4
Piston Area sq. in.	1'17	83	82	29.4	42
H.P. per sq. in Piston Area	0.85	1.45	1.59	3.06	2.73
Piston Area sq. in. per Litre	9.42	8.24	10.8	9.9	11.2
Induction System	Atm.	Atm.	Atm.	Atm.	Atm.
Available H.P.	115	120	130	90	115
Frontal Area per sq. ft.	18.5	18	16.2	14.5	13
H.P. per sq. ft.	6.2	6.8	8	6.2	8.9
Weight cwt.	27.8	28	22.5	16	21.5
Weight with Crew and Fuel	32.3	33	27.5	21	26.5
Engine Litres per Ton Laden	7.56	6	5.5	2.85	3.4
Engine B.H.P. per ton Laden	70	71	95	86	85
Maximum Road Speed m.p.h.	98	100	105	95	116

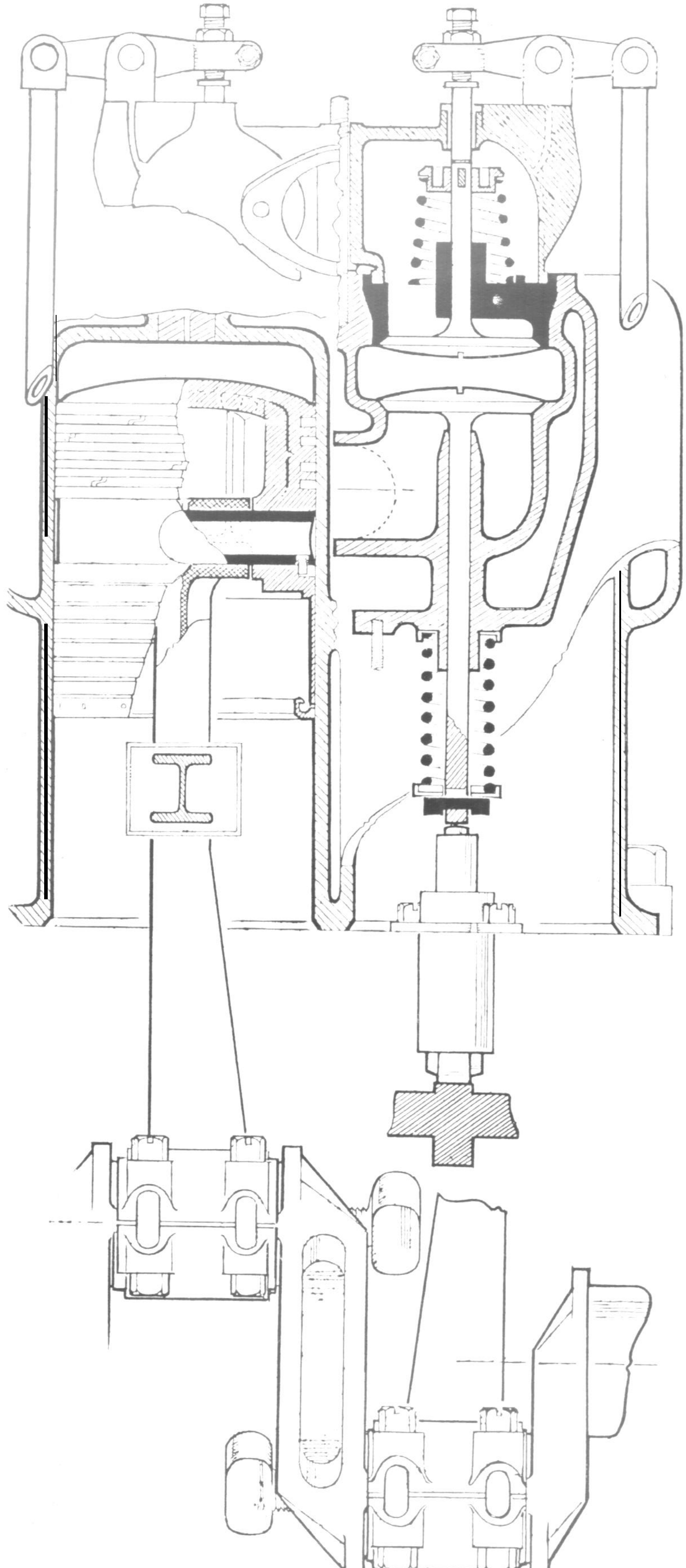
THE most pronounced feature in the map of the first ten years of motor racing is that maximum speeds rose by the order of 30 per cent and average lap speeds by 15 per cent, although engine size, whether measured by capacity or piston area, was diminished by two-thirds. Engine output was higher in the 1914 Grand Prix than it was in the 1906 event (a little below the peak figures realised in 1908 and 1912), and this proves that engine design made rapid strides, which is all the more interesting in that the number of cylinders was unchanged and ferrous material was used throughout for the constructional parts. In round figures, however, crankshaft revolutions were doubled, and piston speeds more than doubled, in this decade, and this could not have been achieved with reliable running without improved metals.

The use of alloy steels was a notable feature. Early engines relied on simple carbon steels for connecting rods and crankshafts, and on cast-iron for pistons. Valves, also, were made from straightforward materials with comparatively poor qualities at elevated temperatures.

In a paper read before the Institution of Automobile Engineers (Volume V, page 190), H. G. Burls stated that a reasonable estimate of reciprocating masses of an engine using cast-iron pistons was given by the formula :

$$M = 0.08d^3 (1 + 0.15r) + 1.5 \text{ lb.}$$

in which M equals mass, d equals cylinder bore in inches, and r equals stroke/bore in inches.



12-litre Engine
of the 1908 G.P.
Itala. Scale 1 : 4.

Taking as a typical case from a number of given examples in an engine with dimensions 130 x 140 mm., the calculated weight was 13.8 lb. and the scale weight 13.2 lb. ; equal to 0.66 lb. per sq. in. of piston area.

The first really high-piston-speed engine, the Peugeot, was also one of the first to employ BND special alloy steels developed by the great continental firm of Derhihon. In addition to being used for many chassis parts and for the crankshaft and connecting rod, this steel was also employed for the pistons which were, therefore, considerably lighter than the cast types hitherto employed. Improved valve steels were particularly necessary in view of the very large step-up in heat dissipated through the exhaust valve head and stem.

Lubrication, a further vital factor in the development of the high-speed engine, changed from the crude drip feed and splash systems, used in the earlier races, to fully forced feed through the crankcase bearings into the crankshaft, a special modification being utilised by Peugeot who circulated the oil through large tanks before bringing it back into the engine. Peugeot again were pioneers in the use of roller bearing main bearings which were copied by Sunbeam ; all the competitors used white metal big ends with thick bronze backing. Pure castor oil was used by most companies.

Compression ratios and brake mean effective pressures did not rise in the same degree as engine speed. Data on the compressions used on earlier cars is meagre but it was of the order of 4 : 1, whereas on the highly successful Peugeot design of 1913 it was 5.3 : 1.

A primary advance was made in gas flow through the valves, whereby it became possible to sustain the b.m.e.p. at high speeds. This was brought about by the obvious means of four valves per cylinder, giving greater valve area in relation to piston area ; less obviously by raising the lift of the valves, increasing their rate of opening, also lengthening the period during which they remained open. It was typical practice on the earlier types of racing car engines to open the inlet valve at top-dead-centre and even slightly after, and to close the exhaust valve at the same point.

Early aircraft engines were probably the first to use " overlap," but the use of this expedient on the 1912 Peugeot was still sufficiently novel to excite comment. However, by opening the inlet valve, say, 15 degrees before top-dead-centre and using a quick opening it will be evident that the total period of the stroke during which the valve was opened for useful work was very greatly increased. A comparison between the timings of the 1903 Mercedes and 1908 Itala and 19 14 Mercedes is of value.

	1903 Gordon *Bennett Mercedes*	1908 G.P. *Itala*	1914 G.P. *Mercedes*	
Inlet Opens	11°	12½°	0°	A.T.D.C.
Inlet Closes	11°	20°	35°	A.B.D.C.
Exhaust Opens ..	45°	42½°	50°	B.B.D.C.
Exhaust Closes ..	6°	0°	9°	A.T.D.C.

It should particularly be noted that in none of the foregoing examples was the inlet valve opened before top dead centre, the relatively small overlap being in every case secured solely by delaying the closure of the exhaust valve. As will be discussed in a later chapter, this practice was continued in the early 1920s.

1913-14 also witnessed the death-throes of any alternatives to the overhead poppet valve plus overhead camshaft mechanism for racing cars. The former year saw the last participation of side-valve engines, the latter the last serious use of sleeve valves, although it is only fair to add that the double sleeve, Knight, type was unsuccessfully employed during the 2-litre formula of 1922-5 and ran its last race in 1931.

There was little uniformity in the matter of drives to the overhead camshaft mechanism. Although a number of designers were influenced by the train of gears employed by Henri in 1913 and subsequently, there were also examples of shaft and bevel drives and (by Vauxhall) a shaft with a worm on the upper end, engaging with wheels at the end of the camshafts. Exposed valve springs and rockers were usual with the object of obtaining maximum cooling and accessibility for adjustment and/or valve spring renewal. The use of double valve springs to eliminate surge points became common.

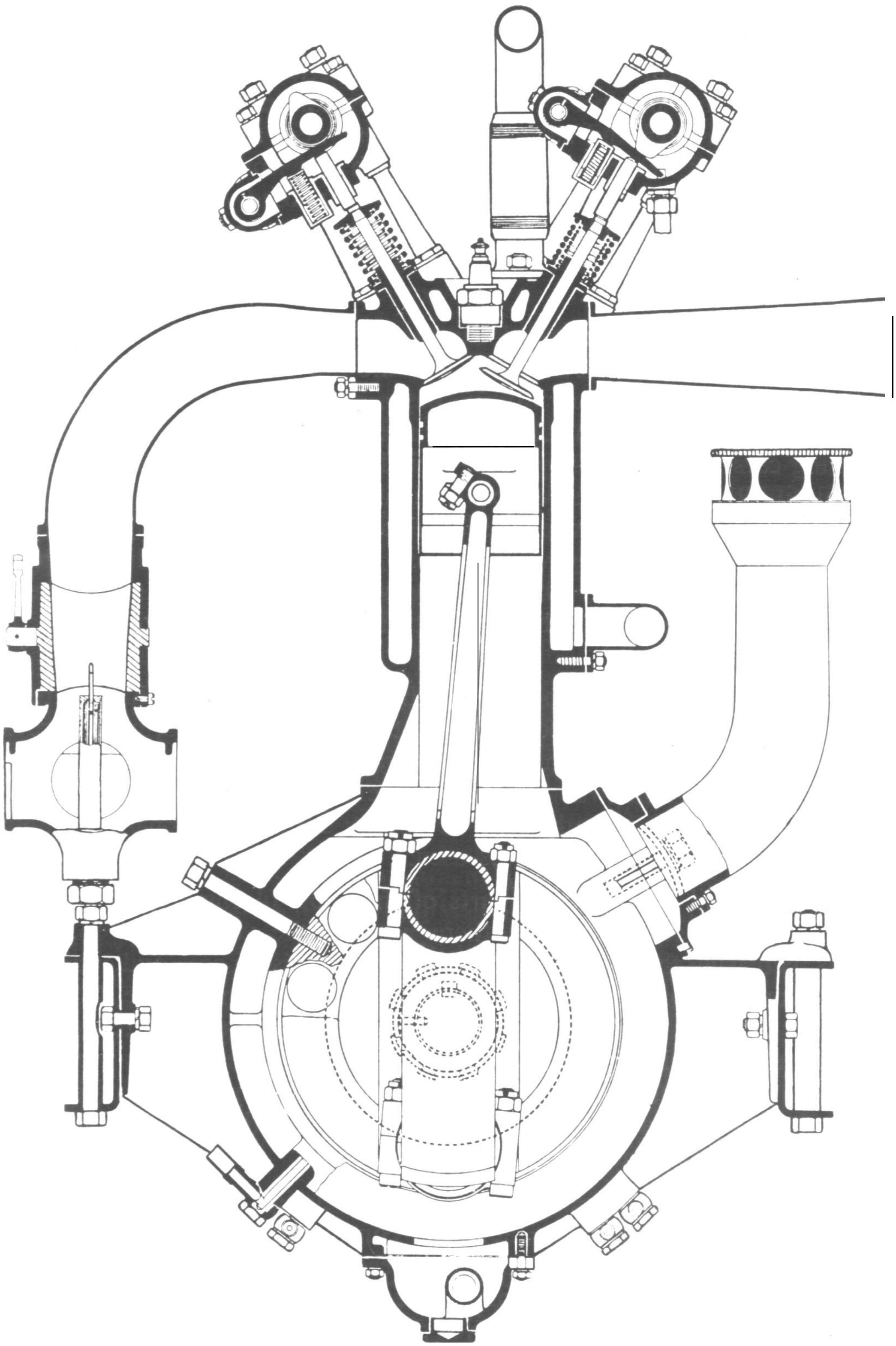
Cooling was materially assisted by the universal acceptance of the integral cylinder head which permitted good water flow around the valve seats, as shown in a number of sections reproduced on various pages of this book. It is of interest that although Gobron Brillie used alcohol fuel mixture in their remarkably successful record-breaking cars in the 1903-7 period, their lead was not followed in Grand Prix racing, and until 1914 all engines ran on straight commercial petrol, supplied by the organisers, and the potential advantages of alcohol in respect of higher permissible compression and internal cooling were neither appreciated nor utilised. Petroleum technology was, however, as yet in the embryo stage, and it was not until the beginning of the second decade of Grand Prix history that fuels were consciously related to engine design.

The fixed choke type of carburetter with barrel throttle, of which Claudel was the chief exponent, was generally used throughout the whole of the period now reviewed, and a single instrument running into a wide branch manifold was normal practice. Fuel feed from the rear tank was by air pressure of 2-3 lb. above atmosphere, this usually being supplied from a hand pump worked by the riding mechanic, although on some early cars exhaust gas pressure was used.

The rotating and reciprocating parts of the 1906-14 engines appear decidedly undersized by modern standards, but there was, as the years went on, a definite trend towards increasing their proportions in relation to piston area and cubic capacity. But analysis of torsional resonance was in its infancy and designers were still calculating crank sizes and gudgeon pin diameters on the basis of required strength to avoid breakage rather than required stiffness to avoid deflection. The stresses were, however, kept well within reasonable limits, as proved by the extreme length of life in these engines, a number of which are still in being and reproducing their designed performance nearly 50 years after their original construction date.

Although in the early stages of Grand Prix car design the multi-plate clutch was most commonly used, the cone type achieved considerable popularity in later years and had the merit of simplicity and inherent freedom from slip. The rotating mass was substantially greater than with the plate type which led Mercedes to use the double cone mechanism described in Example No. 5.

After 1907 not less than four forward speeds came to be accepted as the minimum, with Delage in 1913 initiating the five-speed gearbox with the higher ratio indirect



The 1913, 3 litre, Coupe de l'Auto, Peugeot. Scale I : 4.

and geared up. Fiat, in 1914, built the engine and gearbox in a combined unit (joined through a cast bell housing around the clutch), but all the other cars mounted the box separately on the frame with a foot-operated brake working through the transmission.

In the first four Grands Prix no clear-cut superiority was evinced either by chain or propeller shaft drive, but after continuing with chains in 1913 the Mercedes Company chose the live axle for their 1914 models, and in this they were joined by all other constructors. In this matter, as in so many others, the successful Peugeot of 1912 undoubtedly set a fashion, as it did also in the use of a double-jointed propeller shaft, the drive reaction being taken through semi-elliptic rear springs. Suspension and steering layouts changed scarcely at all, although in order to lower the whole car, there was a general move from 1912-14 towards underslinging the rear springs and in some cases using a double drop frame.

The frames themselves continued to be simple, light constructions of channel steel with a maximum depth of 3 in., but the immense additional stiffness provided, in most cases, by four-point engine mountings at the front, plus four-point gearbox mountings in the centre, should not be considered forgotten. Peugeot represented an opposing school of design which sought to immunise the engine from the effect of chassis distortion by locating it in a three-point mounted sub-frame.

From 1908-14 lowering the height of the top-most portion of the body led to a useful reduction in frontal area. No great effort was made to reduce drag on road racing cars by improved body shape.

In 1914, as in 1906, the typical body consisted of two seats, a rear petrol tank and two spare wheels placed athwart at the back of the car. This, of course, was the simplest and lightest structure, and it was generally held that any possible gain in maximum speed by using a long tail would be offset by impaired handling caused by weight behind the rear wheels and the difficulty of accommodating the spare wheels. Sunbeam used long bodies in 1912 but abandoned them in 1914, but in this year Peugeot and Fiat both used bodies with well-formed tails, the former enclosing two spare wheels in the main structure.

It is generally true that the drag on road-racing cars is not materially affected by changes in shape, but this major modification was undoubtedly worth many m.p.h. ; in fact, Brooklands experience has shown that a gain in speed of up to 10 m.p.h. can be obtained with no change in engine output. It is, therefore, not surprising that this development permanently affected the external appearance of future cars as, of course did the mechanical change introduced *inter alia* by Peugeot and Delage in the shape of brakes on all four wheels.

There was little variation in either dry or running weight between 1906 and 1914 due, of course, to the fact that the regulations in 1906, ‘8, ‘13 and ‘14 prescribed maximum and minimum weights of between 15.7 and 22.6 cwt. For this reason, the h.p. per ton available on the 1914 cars was rather less than that obtained in 1908, the 1912 models representing the peak in this aspect of performance.

In sum the first decade of Grand Prix car design may be considered a period in which engine output rose as a consequence of higher crankshaft r.p.m. and piston velocity, chassis design changed comparatively little and body design scarcely at all. Maximum speeds, however, rose by an average of 5 per cent per racing year and circuit speeds by between 2 and 2½ per cent per racing year.

CHAPTER TEN

Out of the Chrysalis

WORLD WAR I virtually put an end to the design and construction of Grand Prix cars from 1914-8, and when development went forward again in 1919 it was powerfully influenced by aero-engine practice. Once more, however, it was Henri who dominated the intellectual world of the racing automobile, and his post-war products set fashions no less firmly than did his design work in 1912-13. This, in particular, is true in respect of development of the eight-cylinder in-line engine, a type which, in principle, dates back to the earliest days of motoring.

The C.G.V. of 1902 preceded the six-cylinder type and in the 1907 French Grand Prix three makers entered straight eights : Weigel, Porthos and Dufaux.

Nevertheless, when war broke out in 1914 four-cylinder engines had proved overwhelmingly successful for racing cars, only one event, 1911 Indianapolis (six-cylinder Marmon), having been won with a power unit with more than this number of cylinders. It is, therefore, somewhat remarkable that when war was declared again, in 1939, a four-cylinder engine had not won a major race for over seventeen years and with two exceptions (the six-cylinder 2-litre Fiat and Sunbeam) all successful designs had eight cylinders or more. The vast majority had been straight eights.

This change over to multi-cylinder engines in general, and the straight eight in particular, did not come about gradually. It was wrought metaphorically overnight, literally, in two years 1919 and 1920. Hence, whereas in the 1914 French Grand Prix there were no straight eights entered and four-cylinder engines constituted 93 per cent of the entry and 100 per cent of the finishers ; in the next race run in 1921 only two of the starters had four-cylinder engines and all the others were of the straight-eight type. Similarly, at Indianapolis we find that eight-cylinder, in-line engines constituted 13 per cent of the entries in 1919, 25 per cent in 1920 and 56 per cent in 1921.

This remarkable change in racing car design derives from a chain of events which brought together Henri and Ettore Bugatti.

The Peugeots designed by the former have already been the subject of considerable comment and there can be little doubt that following his great successes in 1912 and 1913 this engineer was disquieted, to say the least, at having his designs beaten in the great race of the 1914 Grand Prix, and was determined to have a winner when racing resumed. He realised that this would be delayed in Europe, but Indianapolis was kept alive in the U.S.A. until 1916, and this encouraged Henri to have a design ready for immediate use. He had, however, by then severed his connection with Peugeot and was working for a company called Bara at Levallois in France.

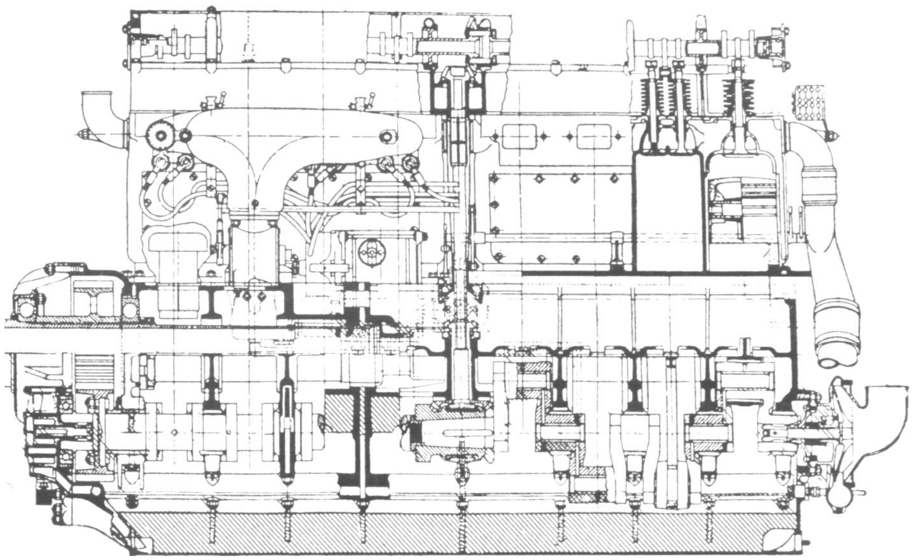
Now to come to the interesting influence of Ettore Bugatti.

From 1910 to 1914 this highly original thinker was working in a very small way, producing two types of four-cylinder cars of widely differing size at Molsheim, then in Germany. One was the progenitor of the four-cylinder, high output, Voiturette, having a bore and stroke of 68 x 100 mm., giving a capacity of under 1½ litres, but

utilising such modern features as an overhead camshaft operating two vertical valves per cylinder.

The other was a similar unit, having a rather different valve gear, incorporating three valves per cylinder, two inlet and one exhaust, but much larger in bore and stroke. A modification of this production type was entered for the 1914 Indianapolis Race and had dimensions of 110 x 160 mm., giving a capacity of approximately 6.25 litres.

In 1911 Bugatti built a straight-eight single-seater racing car with an engine made up of two four-cylinder units (65 x 100 mm.) mounted upon, and running in, a special crankcase and in this year one of these, driven by Friderich, won a hill climb which was probably the first competition success for this type of engine. In 1913-4 Bugatti built a second version of this engine with 68 mm. bore cylinders and thus had a very simply produced straight-eight 3-litre which was kept on the road until well after 1920.



The straight-eight, 12.5-litre Bugatti aero engine built in 1915

The outbreak of the 1914 war prevented development and Bugatti went to France and was asked to design an aero engine. This he did by coupling two Indianapolis four-cylinder engines together on a common crankcase with a camshaft drive in the centre, as shown in a drawing. This engine was built very quickly, and in 1915 it went through a fifty-hour-type test, developing 205 b.h.p. An interesting feature of the design that can be seen is the manner in which the two crankshafts are placed at right-angles (to give a 4-4 firing order) and connected by a taper and key in the centre. This construction gave space for a vertical drive to the camshaft between the front and rear cylinder blocks, a concept that has been followed on many subsequent Bugatti car engines.

It was soon decided that an exceptionally powerful aero engine could be made by placing two of these straight eights side by side, making a " sixteen " with geared crankshafts. The engine developed rather over 400 b.h.p. at 2,000 r.p.m. In 1917 production was put in hand by the Duesenberg Motor Co., in Chicago, and, be it noted, by Bara in France.

Henri thus had very forcibly brought to his notice a straight eight in being, and quickly decided that this was the answer to his problem ; and that his next design should also be a straight eight.

During the war he thought out the engine which was later used in the Indianapolis Ballot cars which, it may be remembered, were constructed in the astonishingly short time of 101 days. With a bore and stroke of 74 x 140 mm. these cars had a capacity of 4.9 litres and were much the fastest on the track. This was shown by the way in which René Thomas easily broke the lap record. In 1914 Georges Boillot on one of the 5.6-litre 1913 four-cylinder Peugeots had made a tremendous effort to reach 100 m.p.h. for a lap but had just failed to do so. Thomas on a brand-new car which had had very little preparation immediately put up a speed of 104.7 m.p.h.

Duesenberg also continued under the Bugatti influence with an engine which was an interesting combination of American and European design practice. In common with the former the crankcase and cylinder block were one casting with a detachable cylinder head. In common with the latter, and Bugatti in particular, it retained three valves worked by a single camshaft. Whereas, however, Bugatti used three cams per cylinder on the Duesenberg the layout was simplified by using a forked rocker for the exhaust valves. The crankshaft, again like Bugatti, was of the 4-4 type.

The general benefits accruing from the use of the multi-cylinder principle have been the subject of a number of papers to learned Societies. A particularly able contribution was made by E. W. Sisman ; " The Straight-Eight Engine " read before the Institution of Automobile Engineers (Vol. XXI). In this he showed that if stroke : bore ratio, compression ratio, and connecting-rod length to crank-radius ratio were kept constant, there were very large advantages to be derived from changing from the four-cylinder engine of 85 x 132 mm. to an eight-cylinder of 65 x 105 mm. At 3,500 r.p.m. the inertia forces would be halved and the maximum explosion load transmitted to the big end reduced by one-third as a consequence of the smaller area of each individual piston. Piston speed at constant r.p.m. would be reduced by 20 per cent and total piston area would rise by 28 per cent.

From these figures it is apparent that increasing the number of cylinders offers much reduced stresses with greater reliability at the same engine speed ; alternatively there is the possibility of raising r.p.m. by 25 per cent without changing maximum piston speed.

When designing the 4.9-litre Ballot, Henri made practically no departure from the proportions which he had established on his 1914 car, and he retained practically identical ratio of engine to road speed, giving 2,600 r.p.m. at 100 m.p.h., the piston speed being reduced from 2,740 to 2,400 f.p.m. It is, therefore, apparent that the stressing on the Ballot engine was substantially lower at a given road speed ; it is also fair to assume the car was faster. Indeed, it is quite possible that under favourable conditions the Ballot engine would run up to 3,000 r.p.m. in top gear, whereas it is unlikely that the Peugeot often exceeded 2,800 r.p.m. The maximum piston speed of the two cars was, therefore, 2,960 f.p.m. and 2,880 f.p.m. respectively. It is thus apparent that Henri compromised between lower stress and increased power-output and worked in the continued belief that 3,000 r.p.m. was the limit for crankshaft speed.

The disappointing results (fourth and tenth) obtained at Indianapolis in the first and only appearance in major racing of this newly designed car might have suggested that it was best to continue on the old lines with four-cylinder engines, but although

the 1919 race might have appeared inconclusive to the layman, engineers were convinced that a new era in design had commenced. Both Europe and America became definitely eight-cylinder minded.

The next big race was the Indianapolis of 1920. For this year the maximum piston displacement was 3 litres and entirely new cars, therefore, had to be designed. Seven eight-cylinder cars were entered, three by Ballot and four by Duesenberg. All the Ballots and three of the Duesenbergs finished within the first ten, and but for accidents an eight-cylinder engine would certainly have won.

Both the Ballots and Duesenbergs were scaled-down versions of the previous year's 5-litre cars, the bore and stroke being 65 x 112 mm. and of 63.5 x 117.5 mm. respectively. The makers' claims were 90 b.h.p. for the Duesenberg and 108 b.h.p. for the Ballot, but in view of their remarkably similar performance the true figures may well lie more closely together.

The 1920 3-litre Ballot was similar to its bigger predecessor but two significant technical changes should be noted. The stroke : bore ratio was reduced to 1.72 : 1 and whereas the big car had followed 1913 body design with a square tail, the small one followed on the lines of the 1914 Peugeot with a long tail body. The rear axle gave a direct drive of 3,150 r.p.m. at 100 m.p.h. and a piston speed of only 2,320 ft./min. at this speed, a fact which permits us to make an interesting comparison between Henri's 3-litre capacity concepts in 1913 and 1920.

A 112 mm. stroke gave the designer a neglected opportunity to put the peak of the horsepower curve at 4,000 r.p.m. without exceeding the 3,000 ft./min. piston speed which had been reached on his 1913 car ; allowing for the further experience of seven years one might suppose that piston speed could be safely raised by, say, 10 per cent, bringing the maximum engine speed up to 4,400 r.p.m. and raising the peak power to approximately 125 b.h.p. but although r.p.m. were increased by 30 per cent. piston speed was reduced.

Henri's hereditary distrust of high r.p.m. was, however, more than justified, since the 3-litre Ballot could never be run to the peak of the power curve for prolonged periods without mechanical disaster. This was undoubtedly due to the combination of a somewhat primitive lubrication system with definitely inferior design of the big end. The former provided dry sump lubrication with only one pump, but considerably limited the pressure at which oil could be supplied, whilst in the design of the big end Henri fell into the double error of offsetting the centre-line of the rod in relation to the centre-line of the crankpin and using a floating bush within the eye of the rod. It has since been shown that the extra overhang area obtained by offsetting is virtually useless, and also that despite having the *prima facie* virtue of reducing the pressure x velocity factor a floating bush has about half the load-carrying capacity of a fixed bearing (*vide* The Load Carrying Capacity of Journal Bearings by J. M. Stone and A. F. Underwood, S.A.E. *Journal,* Vol. I, No. 1, 1947). If we add to these errors a somewhat ill-chosen section for the rod we have ample explanation that the usable maxima of this engine was only 3,500 r.p.m., at which we may assume it developed approximately 100 b.h.p. Thus the dividend paid by the additional complications of the eight-cylinder engine amounted to only 10 per cent on continuous rating compared to Henri's 1913 3-litre despite an increase in piston area of 37 per cent. In short, Henri sowed but did not reap so far as the eight-cylinder in-line engine was concerned.

The principle was used to better advantage by others, notably Duesenberg and Fiat. Both of these power units followed the long stroke theme, but they ran reliably at high r.p.m. and piston speeds, largely as a result of detailed refinements in mechanical construction and lubrication. One must refer immediately to the fact that all the post World War I 3-litre cars used light alloy, in place of iron or steel, pistons.

The Burls' equation referred to in Chapter 18 would assign a total reciprocating weight of approximately 2.7 lb. for a car of 65 mm. bore, whereas the weight of the Ballot connecting rod and piston amounted to only 1.03 lb. or 0.22 lb. per sq. in. The Duesenberg also used extremely light tubular connecting rods and it had in addition pistons of unusually thin section, the total weight of the connecting rod and piston amounting to only 1.15 lb. (0.234 lb. per sq. in.). This was slightly heavier than the Ballot, but the Duesenberg engine was thoroughly reliable ; the Ballot was not. Much of this difference was probably due to the direct babitting of the white metal into the Duesenberg rods with a coating only 1/32 in. thick. By this means heat transfer from the surface of the bearing to the rod was considerably improved, and resistance to cracking substantially raised compared to the extremely thick linings of white metal which were then current practice. Fiat developed the use of roller bearings so that they could be employed for both main and big ends with a solid crankpin. This arrangement, as mentioned earlier in the book, involved splitting the bearing cages of the housings and, in the case of the big ends, using hardened tracks in the eye of the rod itself.

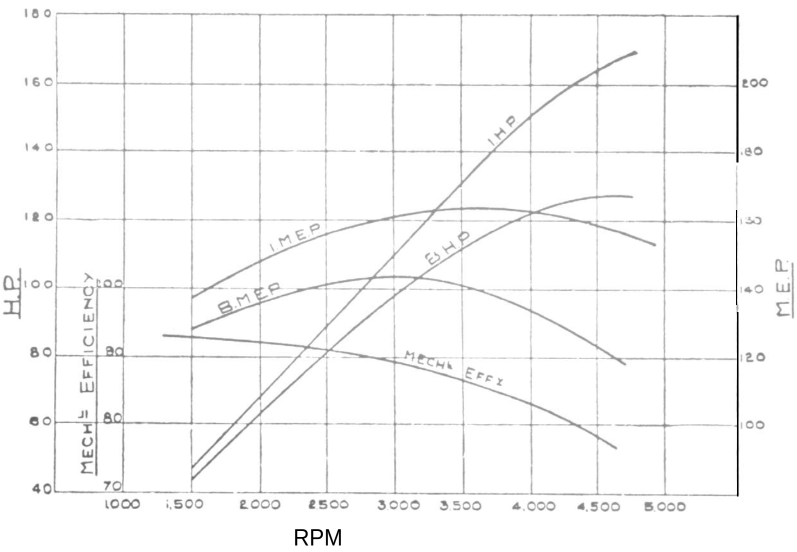
Fiat also carried further the Mercedes scheme of welded steel cylinders, using this arrangement in two blocks of four each having a common water jacket. Both Duesenberg and Fiat (which developed greater power than the Ballot) did so with one inlet valve per cylinder.

The figures for h.p. per square inch of valve area prove that the flow values through the ports was considerably greater per unit of area with a single valve per cylinder than with two, although Ricardo showed what careful design could achieve on the two-inlet valve head of the Vauxhall. Mechanically, the engine of the Duesenberg, which won the French Grand Prix of 1921, showed much of interest, including three-bearing crankshaft, plain big ends, tubular connecting rods, crankcase and cylinder block cast in one, and a detachable cylinder head with one inlet and two exhaust valves operated from a single camshaft. The inclined angle between the valves was approximately 50 degrees, and the drive from crank to camshaft by bevel gears and vertical shaft in the front of the engine.

The Fiat, on the other hand, had a ten-bearing crankshaft, roller-bearing big ends, welded cylinder construction and the valves inclined at an angle of 96 degrees. This naturally gave two widely separated camshafts, which were driven by a train of gears from the rear of the engine.

The Vauxhall 3-litre engine, designed by Dr. H. R. Ricardo, was never used in a Grand Prix event, but by reason of the great technical merit of the design it is worth comparing with its contemporaries. The excellent results were obtained in spite of the limitations on piston area which the four-cylinder principle made inevitable. As on the Fiat the crankshaft was a full roller-bearing type, but Ricardo chose the alternative of a built-up shaft and one-piece connecting rods. The design and performance of this engine are considered in Example No. 7, Volume I, but it is particularly relevant in this analysis to note that the weight of the reciprocating parts was held

These curves show the very high b.m.e.p. and mechanical efficiency that were obtained on the I922 Ricardo-designed 3-litre Vauxhall engine.



down to 1.7 lb. per cylinder, or 0.195 lb. per sq. in. of piston area, which is a good deal lower than the figure obtained on the Ballot and Duesenberg, although both these engines had the advantage of plain bearing big ends.

Reference to the data table shows that the Vauxhall engine operated at 4,000 ft. per min. piston speed ; a substantially higher figure than anything hitherto realised, and one which was, in fact, never exceeded during the subsequent history of racing car engines. This in itself is adequate testimony to the high efficiency realised by Ricardo in what must remain one of the finest manifestations of the automobile engineer’s art.

In view of the decline of a four-valve head in subsequent years it is particularly interesting to compare the flow values of the Vauxhall engine both with the similar four-valve Ballot and the two-valve per cylinder Duesenberg and Fiat.

The figures given in the table show clearly how the Vauxhall valve gear maintained efficiency at high piston speeds ; less clearly the relative merits at equivalent piston speeds. If we fix the Vauxhall power curve at a point where the piston speed is equal to the peak figure on the Ballot, i.e. 3,250 r.p.m., we get the following facts :

Engine	*H.P./sq. in. Piston Area*	*B.M.E.P.*	*H.P./sq. in. Valve Area’*
Eight-cylinder Ballot	2.65 (100)	120 (100)	7 (100)
Four-cylinder Vauxhall . .	3.0 (113)	140 (117)	7.9 (113)

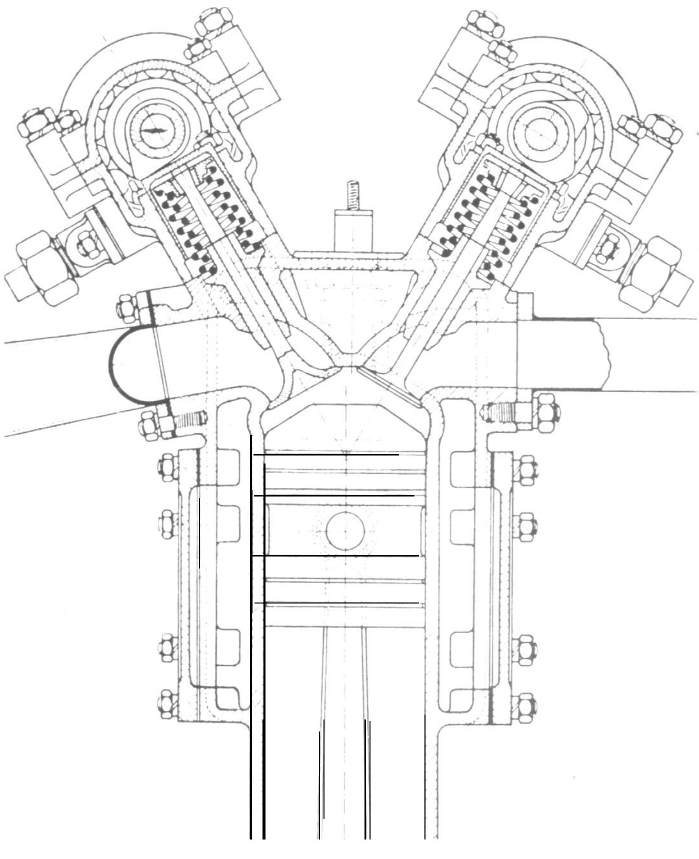
Taking the comparison further with the Duesenberg (of which we have equally reliable data) we have at 3,800 r.p.m. on the Vauxhall :

Engine	*H.P./sq. in. Piston Area*	*B.M.E.P.*	*H.P./sq. in. Valve Area*
Eight-cylinder Duesenberg . .	2.93 (100)	113 (100)	9.6 (100)
Four-cylinder Vauxhall . .	3.4 (116)	127 (113)	8.95 (93)

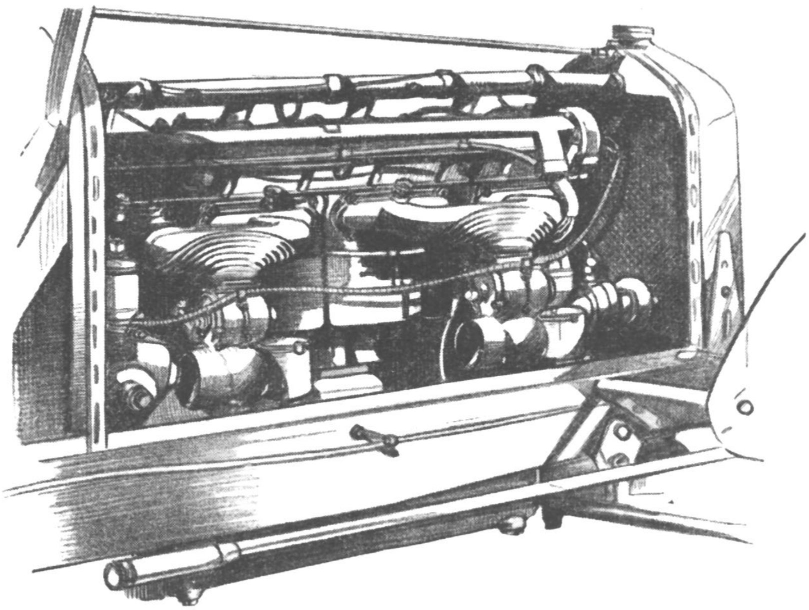
These figures show that the port efficiency on the Ricardo-designed Vauxhall was considerably higher than on the Henri-designed Ballot. It was, in turn, somewhat lower than on the Duesenberg which had only a single inlet valve, but the greater valve area available on the British car gave it a marked superiority in b.m.e.p. and h.p. per sq. in. thus proving that the greater absolute efficiency of a single port could only lead to improved results if it were joined by very large valves and port areas.

The outstanding fact about the immediately post 1914-18 War 3-litre engines was, however, that the highest output of all was secured by a four-cylinder and not by an eight-cylinder engine, despite the many theoretical advantages of the latter.

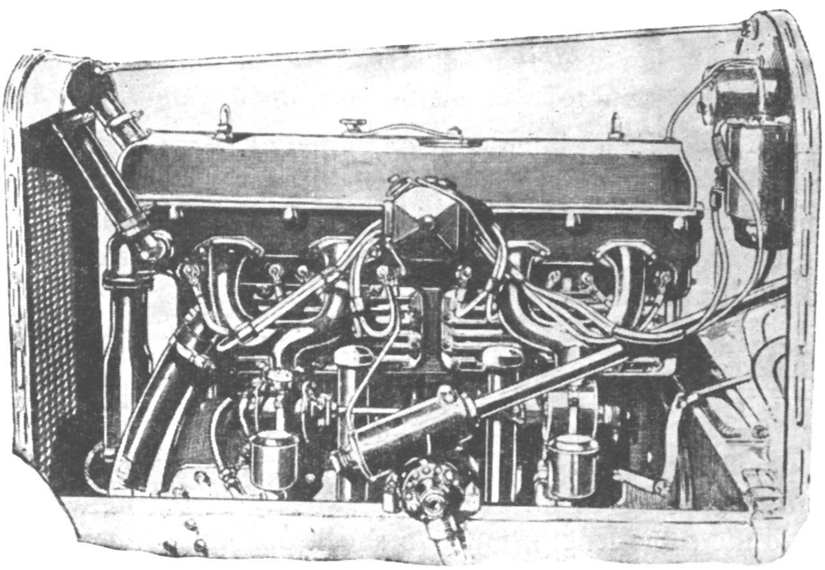
This example of what can be almost laid down as a law of automobile design : " The first concept of superior principle is always defeated by the perfected example of established practice." Thus, the 1914 Grand Prix cars, with four-wheel brakes, were defeated by rear-wheel brake cars in the first contest between them, and the 1919 eight-cylinder Ballot was defeated by the 1914 four-cylinder Peugeot, designed by the same man. In later years, the supercharged engine and independent suspension, were in turn to be defeated on their first appearance. The preliminary setback overcome, we observe that by 1921 the straight-eight engine was firmly established, and although stroke : bore ratio had fallen somewhat from 1914 figures they still remained much above 1908 practice, so that an engine with a ratio of 1.5 : 1 was regarded as a short-stroke type. Nevertheless, there were many minor signs of a break from the almost slavish copying of Henri technique which had been prevalent since 1913. Duesenberg and Vauxhall, for instance, used detachable cylinder heads, Fiats were using wide angle valves and forged steel cylinder blocks, and maximum engine speeds were rising considerably above the limits which Henri imposed upon his products.



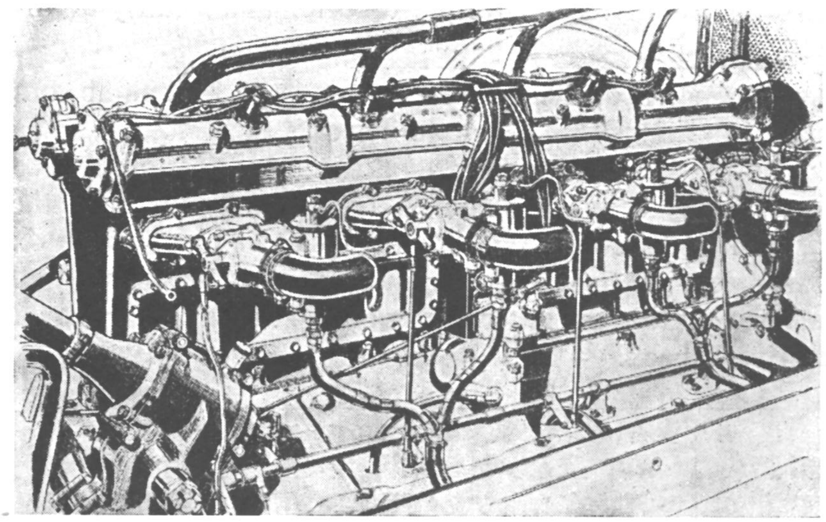
This cross section (Scale 1 : 3) of the 1922 G.P. Aston Martin engine shows the typical four valve per cylinder layout popularised by Henri on the immediate post 1918 racing cars.



Left.-The first racing car to have a straight-eight engine was the Henri-designed Ballot of 4.9~litres capacity entered for the 1919 Indianapolis Race. It was easily the fastest car. Although unsuccessful owing to trouble with wheels, it set a lead for the straight-eight which has since been followed in the majority of racing power units.



Right.-In 1921 the eight-cylinder in-line engine received the seals of success, winning the Indianapolis Race in America and the French Grand Prix. The American Duesenberg Corporation, which had built the Bugatti aero engine in the previous war years, provided the winner for the latter event, and the induction side of the engine is shown in this drawing.



Left.-One of the few English straight-eight racing cars was the 1921 Sunbeam that ran in the Indianapolis and the French Grand Prix races that year, although without great success. The drawing shows its general similarity to the Ballot design, although the manifolding and many other details are quite different.

So far as chassis design is concerned, the 1919 to 1921 period does not display any considerable novelty. The successful use of front-wheel brakes in 1914 naturally led to these components being standardised on the cars of the post-war era. In this field Perrot was responsible for most of the equipment, with Birkigt designing an ingenious servo mechanism which would give a high unit pressure on the brake shoes with reasonably light pedal pressure, despite the mass of mechanically inefficient compensating mechanism which usually existed between the pedal and the brake drum.

There was a further factor which biased designers in favour of servo assistance on the brake pedal. At this stage in the history of automobilism, brake linings had relatively poor resistance to wear, and to fade at high temperatures. By reason of the latter defect high surface pressures were required, and by reason of the former the leverage between the pedal and the shoe had to be kept to a minimum so that slight wear on the lining would not be translated into a very large loss of useful travel on the pedal, leading in turn to the imperative need for “ taking up ” the brake rods or cables. The servo mechanism made it possible to combine relatively small mechanical advantage with high shoe pressure and low pedal pressure.

Duesenberg provided the first example of successful hydraulic brakes in racing. The brake shoes themselves were made from a flexible strip of metal with multiple segments of lining attached thereto. Although this arrangement did not become popular they were undoubtedly efficient.

Fiat had an interesting combination of mechanical brakes assisted by a hydraulic servo motor. The use of compressed air braking on the 3-litre Vauxhall was unique and cannot properly be considered as servo assistance as it was controlled by a lever on the steering column. Alternatively, pedal and hand levers could apply direct effort to the brake shoes.

Semi-elliptic springs with friction shock absorbers were standard at the four corners of the chassis.

The effect of greater unsprung mass on suspension was, however, becoming apparent. A typical 1907 racing car had front springs measuring 35 in. between centres and rear springs 39 in. with comparatively light damping. On the 1921 Ballot the leaves were the same length, but two shock absorbers were fitted to each spring so that the damping was very materially increased.

The relative merits of Hotchkiss drive and torque tube remained fairly evenly balanced in designers’ minds.

So far as body designs are concerned, the 1919 Ballot (and the 1921 Sunbeams which were derived from it) had square tails, but some other cars were notable for a real effort towards streamlined form. The Duesenbergs, particularly, possibly due to their track racing traditions, had really beautiful lines. A typical body width at the largest section can be taken as 32 in., i.e., about 5 in. less than that of the Grand Prix cars of 1914. Despite this it was possible to have both the driver and mechanic well enclosed by staggering the seats and putting the latter back about 4 in. so that he could put his right arm behind the driver’s back.

CHAPTER ELEVEN

End of a Theme

WE have seen how the general proportions of racing car engines became almost standardised between 1913 and 1921 under the influence of the highly successful work of Henri. Engines designed by him or his disciples had the following characteristics :

(1) A stroke : bore ratio of between 1.7 and 2 : 1 giving a compact combustion space with good thermal efficiency.

(2) Four valves per cylinder inclined at approximately 60 degrees, giving a high ratio of inlet valve to piston area. Each row of valves was operated by its own camshaft and the sparking plug was fitted centrally between valve seats.

(3) A barrel-type crankcase in which the built-up crankshaft ran on roller main bearings with plain big-end bearings.

(4) A limit of approximately 3,500 revolutions per minute.

(5) From 1913 onwards, a steady diminution at piston speed, brought about by the use of eight cylinders and reduced absolute stroke, despite the continued large stroke : bore ratio. To be specific the 1913 four-cylinder, 3-litre Peugeot engine had a stroke of 156 mm., and a piston speed of approximately 3,000 ft./min. at 2,900 r.p.m. ; the 1920-l eight-cylinder, 3-litre Ballot engine had a stroke of 112 mm. and a piston speed of 2,600 ft./mm at 3,500 r.p.m.,

A 2-litre, eight-cylinder, four valve per cylinder, engine, with a typical Henri stroke : bore relationship of 1.8 : 1 would have had a bore and stroke of 51 x 92 mm., and the valve diameter would be reduced to approximately 20 mm. Assuming 5 mm. to be the minimum diameter of valve stem there would be a severe friction loss through the ports, and at the established piston speed of 3,000 f.p.m. the crankshaft would be turning at 5,000 r.p.m. Hence, in 1922, Henri had to do one of two things, reduce the stroke: bore ratio and raise r.p.m. for the multi-cylinder engine, or maintain his tenets and meet the 2-litre formula with a four-cylinder engine. In designing the 1922 Sunbeam car he chose the latter course and used a four-cylinder engine, 68 x 136 mm., which followed precisely along the lines of previous designs.

Henri was additionally, if indirectly, represented by two other entries in the 1922 French Grand Prix—the four-cylinder, 2-litre Ballots, and the 1½-litre, four-cylinder, Aston Martins. The former engines had been designed by him in 1920 and one of them had finished third in the 1921 French Grand Prix, despite the handicap imposed by competing against 3-litre cars. These engines had a bore and stroke of 69.9 x 130 mm. (1.86 : 1) and the only departure from Henri's conventional layout was the drive to the camshafts, which was by a vertical shaft and bevel gears in place of the usual train of spur wheels.

The engines used in the Aston Martin cars were actually designed (so far as the cylinder block and head are concerned) by Gremillon, a member of the Peugeot drawing

office, the work being commissioned by Count Louis Zborowski and carried out under the supervision of Captain Clive Gallop. By courtesy of the last named it is possible to reproduce drawings of this engine, which show that the designer had drunk deeply from the waters of the Henri stream, indeed, the similarity between this engine and Henri's eight-cylinder Ballot is particularly noticeable, not only in respect of having identical bore and stroke (which was fortuitous), but also in the layout of valve gear, sparking plug position, and so on. The valve timing, moreover, was precisely as used In the Peugeot engines of 1913-4, being :

Inlet opens 3 degrees A.T.D.C. Inlet closes 40 degrees A.B.D.C.
Exhaust opens 56 degrees B.B.D.C. Exhaust closes 12 degrees A.T.D.C.

The piston areas for the three makes inspired by Henri were Aston Martin 20.6 sq. in., Sunbeam 22.5 sq. in. and Ballot 23.8 sq. in. Engines of this period gave *circa* 2.7 h.p. per sq. in. of piston area at 3,000 f.p.m. piston speed, and on this basis the estimated outputs would be 61 b.h.p. at 3,500 r.p.m. on the Sunbeam, 64.5 b.h.p. at 3,500 r.p.m. on the Ballot and 55.5 b.h.p. at 4,100 r.p.m. on the Aston Martin. Peak figures realised on the brake were 55 b.h.p. at 4,200 r.p.m. on the Aston Martin, 70 b.h.p. at 3,800 r.p.m. on the Ballot and 83 b.h.p. at 4,250 r.p.m. on the Sunbeam.

Obviously Henri was wringing the last ounce of b.m.e.p. out of the engine he had designed, for he was obtaining 3½ b.h.p. per sq. in. of piston area at 3,640 ft./min. piston speed, but good as these results were they were inadequate to meet newer types of engine with larger piston area and greater r.p.m. The Henri theme had been originally applied to engines of fairly large capacity and moderate r.p.m. ; admirably in harmony with these requirements it was incapable of counterbalancing diminished swept volume, not only from geometrical weaknesses, but also by reason of certain mechanical defects common to this designer's constructions. Henri was wedded to running crankshafts on roller main bearings with plain big ends, and the latter could, therefore, only be lubricated by jets, or, to put it more crudely, by splash. They were, therefore, fundamentally unsuited for high speed operation, which demands a copious supply of pressure oil to plain bearings (for both lubrication and cooling) or, alternatively, ball or roller bearings throughout.

The year 1922 saw the advent of the full roller-bearing engine into Grand Prix racing. The senior members of the Fiat Technical Department, Fornaca and Cavalli, had under them a team of brilliant designers, including Zerbi, Bertarione and Becchia. In 1921 they had produced a superb design for the 3-litre formula which embraced welded steel cylinders and a one-piece crankshaft with full roller bearings, using split housings for both main- and big-end bearings. Additionally, they had discarded the four-valve head in favour of two ports per cylinder, offering better flow values, the total valve area being sustained by placing the valves at an included angle of nearly 100 degrees. The eight-cylinder engines had had the dimensions popularised by Henri, viz. 65 x 112 mm., and as a simple means of producing a 2-litre version for 1922 the number of cylinders was reduced to six, the stroke reduced to 100 mm., and the bore left untouched.

Using the same fundamentals that were applied above we see that the Fiat engine (with a piston area of 31 sq. in.) was capable of giving 84 b.h.p. at 4,600 r.p.m., and in point of fact, owing to the superior mechanical construction, it could be run at 5,200 r.p.m. with an output of rather over 90 b.h.p. equal to 3 b.h.p./sq. in. at 3,420 ft./mm. piston speed.

The only other serious competitor in 1922 was Bugatti, who created an entirely original design. Using eight cylinders with a bore and stroke of 60 x 88 mm. his engine was, within the frame of reference used in this analysis, capable of 94 b.h.p. at 5,200 r.p.m. but as he, also, was at this time an exponent of roller main bearings with white-metal big ends, the realised power of his engine was substantially below the theoretical possibilities.

In the French Grand Prix at Strasbourg in June and in the Italian Grand Prix at Monza in September, the Fiats were overwhelmingly successful ; thus after nine years of renown the Henri theme was completely discredited and utterly cast down within a space of three months. For the next six years the Fiat school of design was in the ascendant. This was as true in the realm of chassis design and the general form of body work as it was in the realm of engine layout.

The frame of the Strasbourg Fiat was in-swept in plan so that it followed the lines of the tapering wedge-shaped tail. The body was comparatively flat-sided and as can be seen from illustrations, the appearance was notably different from the comparatively barrel-shape, long-tailed cars which had come directly after the square-backed bodies used until 1914. On the Fiat even the exhaust pipe was moulded into the body's side, giving a clean appearance which promoted a definite fashion during the next three years, and an easily recognisable inspiration to other designers for more than a decade.

Owing to the narrowness of the frame at the back it was necessary to hang the rear semi-elliptic springs on to a cross-bar, and at the front the spring leaves were passed through the axle beam in the manner pioneered on the 1914 Vauxhall Grand Prix cars. In accordance with current practice, four-wheel brakes were servo operated, oil pressure being used to increase the effort of the driver's foot, but with diminishing all-up weight the mass of the brake drums began to have a very undesirable effect on road holding.

Ready for the starting line, with crew aboard, the 1922 Fiat was some 4 cwt (nearly 20 per cent) lighter than the previous year's Ballot, but there was but little change in the unsprung weight. On these 2-litre cars, therefore, we see the first step towards stiff springs giving very limited travel, adhesion being to some extent deliberately sacrificed in the interests of high speed stability.

The breakaway from Henri design in the Fiat transmission was as marked as in the engine layout. As we have seen, the former popularised the Hotchkiss-drive for racing cars, but the Fiat successes focused attention on the torque tube rear axle with only one universal joint and rear springs free to perform with no extraneous loading. Bugatti used reverse quarter-elliptic springs with an external torque arm ; and also continued to employ a separately mounted four-speed gearbox.

The light weight of the 2-litre Fiat cars has already been touched upon but this notwithstanding, the performance factors of the car compare unfavourably with both preceding and following Grand Prix models on account of the comparatively low maximum power available. In consequence, only 7.6 h.p. was produced for each square foot of frontal area and the output per laden ton was only 102 h.p.

The 1923 season was remarkable for three things, In the French Grand Prix the only serious rivals were Fiat and Sunbeam, for Bugatti prejudiced his chances by introducing an envelope-type streamlined car with proportions of wheelbase to track which were both unorthodox and unsuccessful. The second feature was that the Sunbeam Company had built, under the direction of Bertarione, who had been secured from Fiat for the purpose, a six-cylinder 2-litre engine which was almost a replica of the previous year's Strasbourg Fiat. The cylinder bore was enlarged by 2 mm. and the stroke reduced by 6 mm., and by detail attentions the output was raised from 85 b.h.p. at 5,000 r.p.m. when first constructed to 102 b.h.p. at the same engine speed as raced at Tours. The chassis remained almost unaltered from the 1922 Henri car, but the body work was rebuilt along Fiat lines.

We may presume that an additional 10 b.h.p. raised the maximum speed of the Sunbeam to about 110 m.p.h., and this, coupled with complete reliability, was sufficient to win the French Grand Prix.

The third, and most vital, contribution of 1923 in motor racing history was, undoubtedly, the introduction by Fiat of supercharging to Grand Prix racing. Mechanical troubles prevented these cars from winning at Tours, but technically they were so clearly superior that they had virtually a walk-over in the 1923 Italian Grand Prix at Monza three months later. The introduction of supercharging was indeed a matter of so great moment that it has to be considered in a separate chapter.

CHAPTER TWELVE

The Beginnings of Blowing

THE introduction of the twin-camshaft engine in 1912 ; front brakes in 1914 ; and the eight-cylinder in-line engine in 1919 exerted permanent effects upon subsequent racing cars, but none of these changes had such potentially far-reaching consequences as supercharging which added, as it were, an extra dimension in engine design and led to tremendous developments in fuel, cooling problems and, in the long run, to the maximum power available, irrespective of engine capacity.

The gains to be derived from the use of a blower were obvious at an early stage in automobile history and it appears that the first idea of supercharging came from the brain of Louis Renault in 1902, in which year he patented an arrangement in which a centrifugal fan blew air into the mouth of the carburetter.

In 1905, Lee Chadwick, with the assistance of his able engineer, John T. Nichols, designed a six-cylinder car called the Type 15 with a bore and stroke of 127 x 152.5 mm. This was about 5 m.p.h. faster than preceding four-cylinder models, but in this, and in various other ways, the car was not wholly up to expectations. It was replaced by a Type 16 in 1907 which had *inter alia* larger inlet valves and was followed by a Type 19 with overhead inlet valves of exceptional diameter. These did not provide the gain in power that was expected, the power curve dropping off sharply on the higher ranges of r.p.m. This led Chadwick to suggest to Nichols that the carburetter be put under pressure in order to secure at least 100 per cent volumetric efficiency at high engine speeds.

The first experiment embraced a single-stage centrifugal booster driven at nine times crank speed by a flat belt from the 18-in. flywheel. The results were excellent and led to a decision to ensure actual supercharging of the cylinders by means of a higher pressure booster in three stages. This was driven, again at nine times engine speed, by a 2-in. Vici leather belt. Two universal joints were fitted in the drive to permit belt adjustment and keyed to the driving shaft were three 12-bladed impellers all of 10-in. diameter but of varying width so as to provide the required three stages of compression. Air was delivered to the carburetter under pressure and received from a pipe running up to the back of the radiator core which was intended to give some ram effect. This pipe was jacketed and fed with hot water.

As evidence of the advanced thinking by Chadwick at this time this layout was adopted after serious consideration had been given to an exhaust-driven blower and success was immediate. The car was entered for, and won, the Wilkes Barre Hill Climb on May 30, 1908, and was thus victorious in the first event for which a blown engine was entered. On October 24, of the same year, the car was lying third on the first, and second on the ensuing two laps, of the Vanderbilt Cup Race. Haupt, who was driving, took the lead in the fourth lap which he retained up to the sixth. He was then put back by magneto trouble caused by some extraneous brass nuts which had been placed within the contact breaker case. In the Savannah Grand Prize the car broke down from the after effects of an accident which had taken place on the road

prior to the race. In subsequent U.S. events many wins were recorded, the most important being the 200-mile road race at Fairmount Park in 1910.

Replicas of these cars were sold to the public and one was timed by the A.A.A. to exceed 100 m.p.h.-almost certainly the first catalogued model to achieve such a speed. Well over 110 m.p.h. was frequently realised on these vehicles but in 1911, Chadwick abandoned his automobile interests, and although he had made no effort to hide his work, it was not until 1923 that it was continued by Miller and Duesenburg with the assistance of Dr. Sanford Moss.

In Europe, the first serious attempts to supercharge a racing car engine were made in 1911, by Sizaire, who experimented with a centrifugal blower, and by Birkigt, who carried out some most interesting experimental work with a piston type displacer on a car intended for the 1912 Coupe de l'Auto. This was described by W. F. Bradley, the Continental correspondent of *The Motor,* who stated that nearly 100 h.p. was being obtained from a 3-litre engine. Drawings supplied by him showed that it was an intelligent adaptation of the existing T-headed Hispano Suiza engine with four additional cams on the inlet camshaft. Each of these opened an overhead inlet valve which received mixture from a separate carburetter through the intermediary of a rotary valve placed centrally in the cylinder head. By this means it was possible to draw in the normal charge to the normal inlet system, the piston type displacer (which is expensive in size and weight for a given swept volume) being relied upon solely for the additional volume required to supercharge.

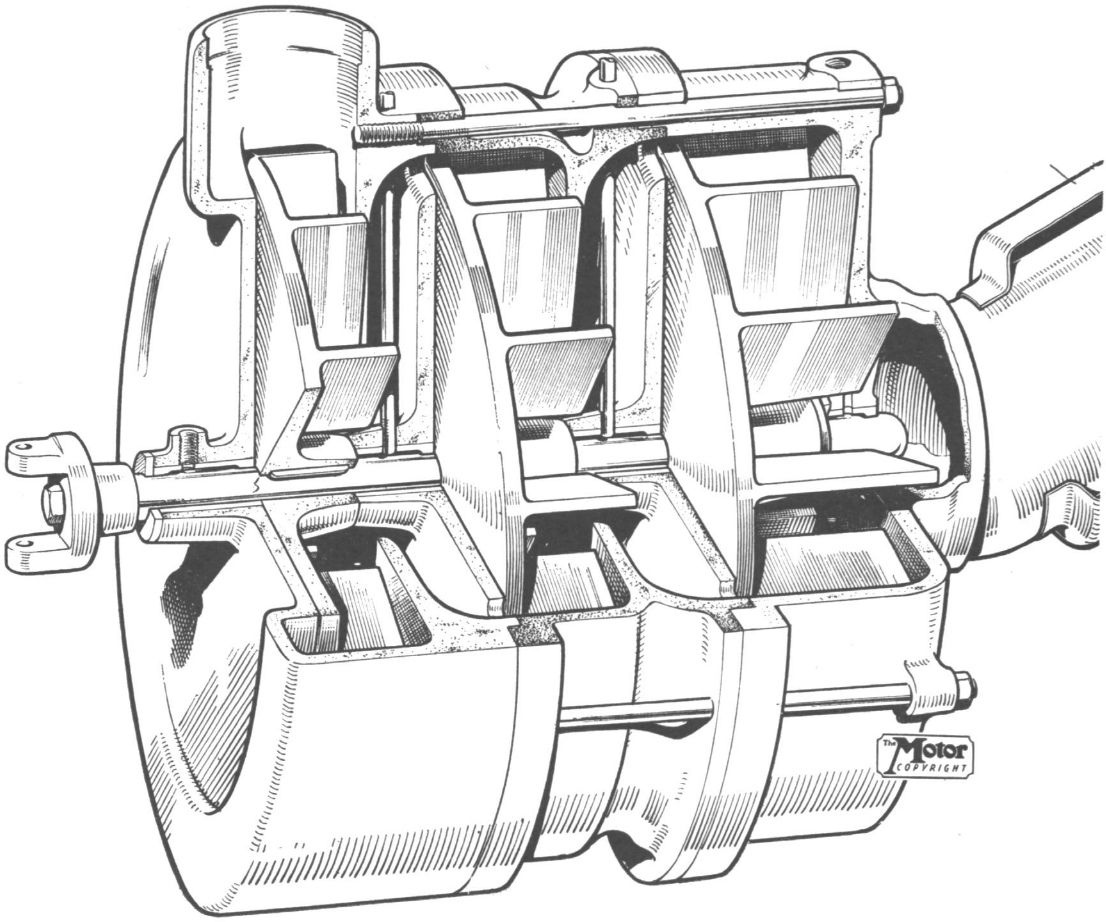
Development troubles prevented this engine from appearing in the race, and in the subsequent year superchargers were forbidden on the 3-litre cars entered for the Coup de l'Auto race, as they were in 1914 under the regulations setting a limited 4½-litres for the Grand Prix at Lyons.

The 1914-18 war put a full stop to European racing, but it focused attention on supercharging as a means whereby aeroplane engines could retain good power at height despite the natural reduction of air density. Towards the end of hostilities German engineers were paying particular attention to this problem, and as soon as it was possible to consider peace-time projects, the manufacturers of the Mercedes car began to study the question of supercharging road vehicles.

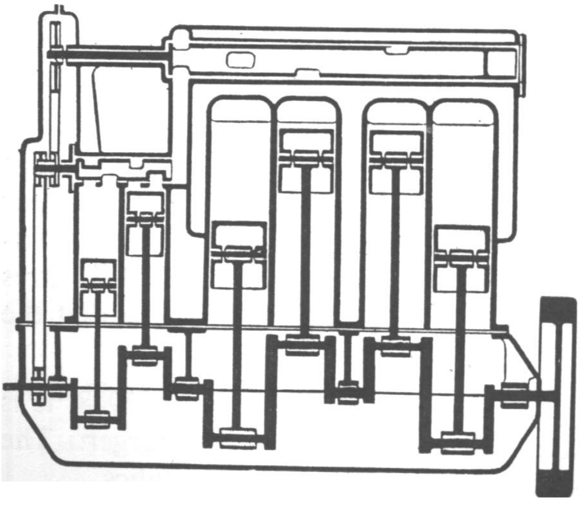
The first pump used by Mercedes was a piston compressor with three radial cylinders. This was discarded in favour of a vane-type pump patented by Wittig. Mercedes, however, experienced mechanical and lubrication troubles with the Wittig and turned to the Roots blower. All the original experimental work was carried out on either aero-engines or submarine power units.

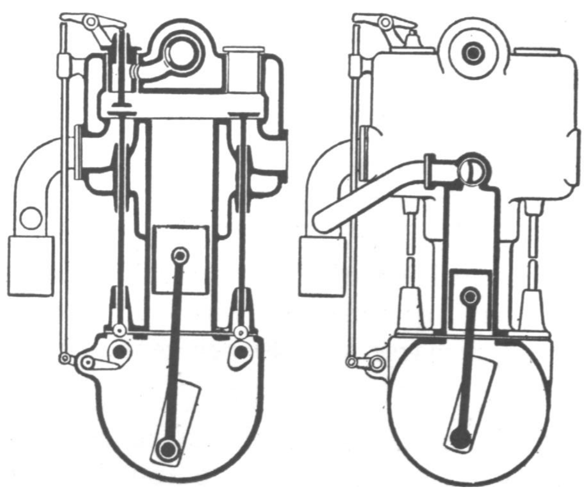
Development on automobiles was initiated in September, 1919, with a Roots blower running at a maximum speed of between 8,000 and 10,000 r.p.m., fitted to a Mercedes Knight sleeve-valve engine as it was thought that this valve gear would reliably withstand a higher thermal loading than the poppet-valve type.

Trials began in mid-October of 1919, and these quickly proved that the sleeve valve was incapable of standing up to the extra heat involved, the oil burning badly near the exhaust port and leading to seizure of the sleeves. The experiments were, therefore, continued with the poppet-valve type of engine and a supercharged 28/95 six-cylinder Mercedes was entered for the Coppa Florio race of 1921. Driven by Max Sailer, this car won the first victory in racing for a supercharged model.



These drawings show alternative systems of supercharging. developed by Chadwick in the U.S.A. in 1907-8 and Birkigt, in Paris, in 1912. The American arrangement used a centrifugal blower driven at nine times engine speed, so that the rotor speed was about 18,000 r.p.m. The rotor diameter was 10 in., giving a tip speed of 700 ft./sec. As can be seen from this drawing, compression was divided into three stages by varying the width of the rotor blades, the air passing through ports cut in the dividing walls between the three sections In the Hispano-Suiza layout a double piston pump was driven from the nose of the crankshaft, this being connected with a supplementary overhead inlet valve placed in the T-head. By using phased rotary valves for the displacer it became possible to have normal aspiration through the carburetter for most of the inlet stroke followed by a pressurised surcharge in the last few degrees of crank travel. Although this experimental engine was not raced, it is claimed to have given 100 b.h.p. from 3 litres capacity.

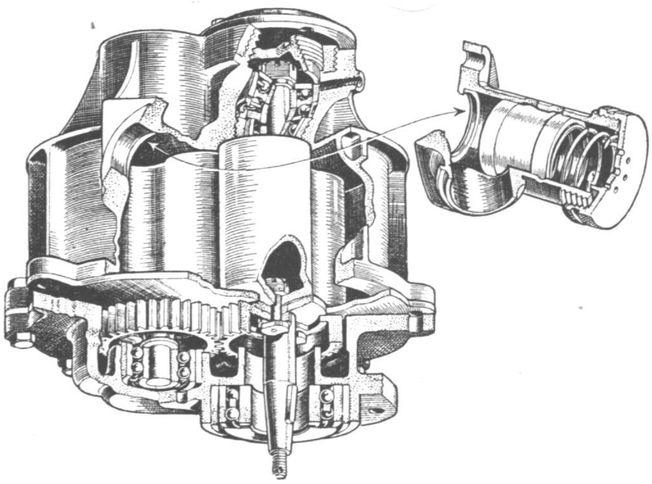


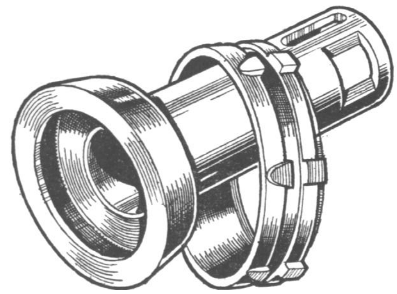


Thus encouraged, Mercedes designed a sports 1½-litre car with a supercharger.

Two of these cars were entered for the 1922 Targa Florio Race, driven by Scheef and Minoia ; they had poor brakes and road holding, one of them retired and the other finished twentieth–twenty minutes behind a tuned standard Fiat and forty minutes behind an o.h.v. Fiat of the same capacity.

One of these cars came to England and it is thus possible to show the full working of the device which is as follows. A small Roots blower mounted vertically at the front end of the crankcase and driven by bevel gears at 2.2 times engine speed forced air into the carburetter only when the throttle pedal was fully depressed, a feature that was characteristic of almost all Mercedes supercharged engines up until 1937.





Details of the Roots pump driven at 2.2 times engine speed on the 1½-litre Mercedes. On the right is a drawing of the clutch-shaft which engaged the blower at full throttle.

The driving bevel was connected to a large drilled sleeve internally splined and fitting into these splines was a light floating bush which had a coned face. The drive from the crankshaft was transmitted through a male cone member which could be drawn into engagement with the loose bushes, thus connecting up the supercharger drive and providing full boost. This cone clutch was connected to the accelerator pedal and further linkages cut off and sealed the normal air intake to the carburetter which then received only pressure air from the blower.

The float chamber had to be sealed and it was necessary for the fuel to be delivered at a higher pressure than the supercharged air, otherwise it would be impossible to replenish the carburetter. This was achieved by mounting a small rotary pump on top of the blower. When the latter was running, this auxiliary pump forced fuel into the carburetter ; when it was not running, fuel was circulated past the working clearances of the pump by the normal air pressure in the fuel tank.

It is interesting to note that the supercharger, as fitted, had a theoretical swept volume of approximately 600 c.c. which gave it a theoretical output of 1.32 litres per engine revolution, taking into account the ratio of the gearing. If we assume a volumetric efficiency of 80 per cent. the charge of air displaced was approximately 1.05 litres per r.p.m., as compared with 0.75 litre, which would be naturally induced, so that the net supercharge was 40 per cent., or approximately 6 lb. per sq. in.

By the courtesy of Lord Ridley, the owner of a car of this type in 1948, it is possible to publish results of bench tests made with and without supercharger. The figures are as follows, the output in supercharged form being shown in italics.

STATISTICS FOR 1922 MERCEDES 1½-LITRE ENGINE

R.P.M.	*B.H.P.*	*B.M.E.P.*	*H.P. per sq. in. of piston area*
1500	19	109	0.88
2000	27	112	1.25
2500	36	120	1.67
3000	45	124	2.1
3500	49 *65*	116 *153*	**2.24** *3.1*
4000	54 *72*	112 *150*	2.5 *3.35*
4250	*75*	*148*	*3.5*
4500	*79*	*147*	*3.68*
4750	*82*	*145*	*3.8*

In sum, three principal features characterised the initial application of supercharging to the 1922-3 Mercedes cars. They were :

(1) The supply of pressure air to the carburetter.

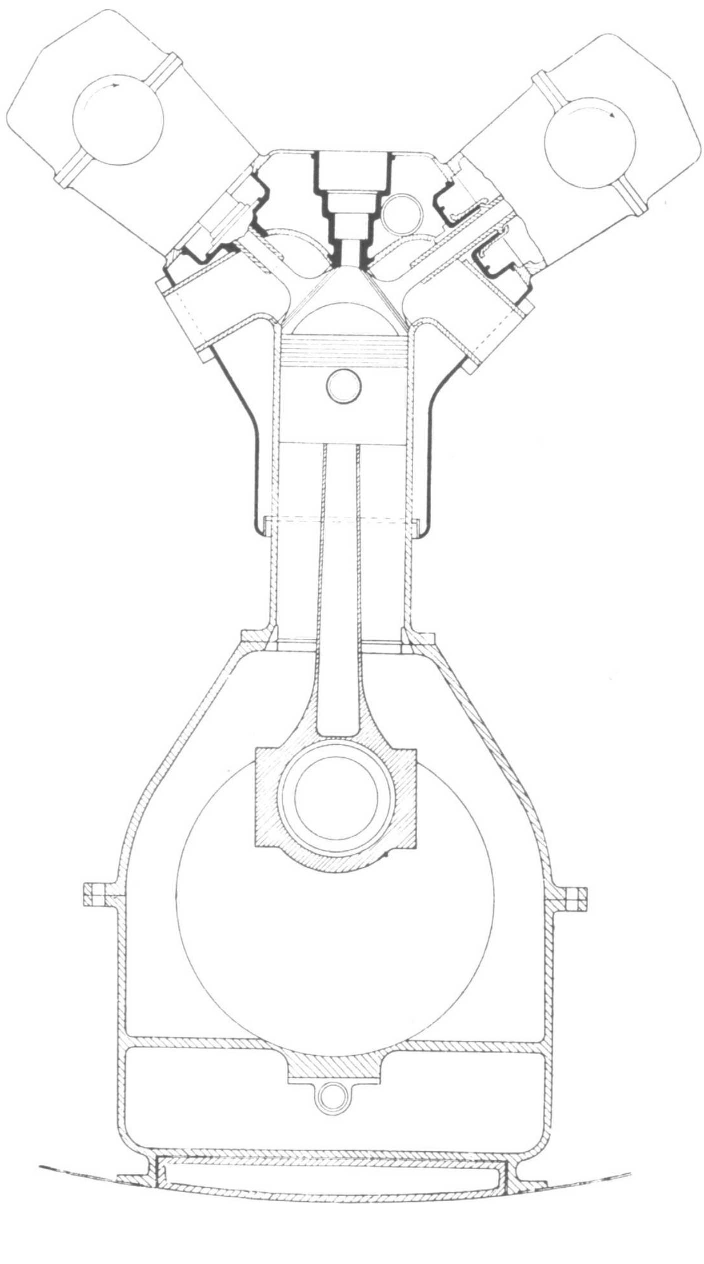
(2) The temporary engagement of the blower on full throttle in order to achieve brief periods of overload.

(3) A substantial step-up in output. The gain at 4,000 r.p.m. (3,000 ft./min. on the 1922 l½-litre model) was 34 per cent ; the overall increase some 50 per cent.

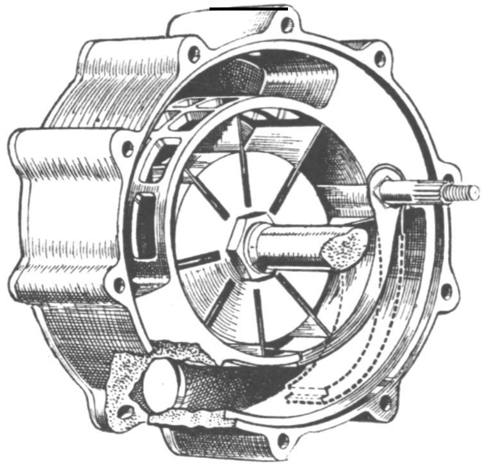
The application of supercharging by Fiat, the first company to use the principle in Grand Prix racing, was somewhat different. They used the Wittig vane-type blower which had been tried and discarded by Mercedes in 1919, but it was coupled permanently to the nose of the crankshaft and ran at engine speed. A drawing shows that the delivery side of the casing was made in the form of a hinged flap, so designed that it could be swung aside, whereupon the vanes would rotate without positively displacing any air. Hence, Fiat, like Mercedes, regarded the supply of pressure air as a temporary expedient for brief periods and ensured that the driver could in effect engage or disengage the supercharger at will. Furthermore, and again following Mercedes practice, the blower pumped air only into the carburetter. This necessitated a sealed float chamber and a mechanical pump was used capable of supplying against the supercharge pressure, this pump having an overriding hand control for use in emergencies.

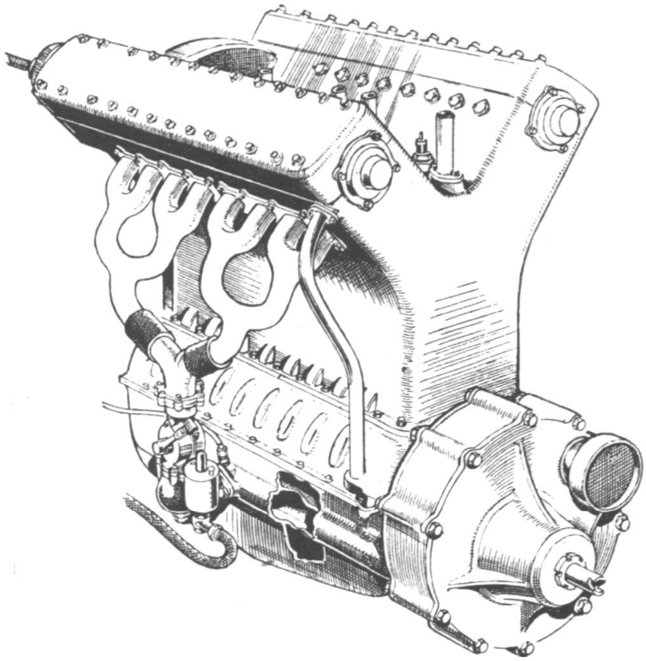
But, unlike the Mercedes experiments, the effect of the Fiat-Wittig blower on engine output is not easy to assess because it was applied to a new type of engine which, although falling within the 2-litre capacity class, had a greater piston area than the unsupercharged type used in the previous year. From published information we can, however, set out a table of comparison.

Car	*Cyls.*	*Bore*	*Stroke*	*B.H.P.*	*R.P.M.*	*F.P.M.*	*B.M.E.P.*	*H.P./sq. in.*
1922 Monza Fiat	6	65	100	118	5,000	3,280	145	3.6
1923 Fiat-Wittig (S)	8	60	87.5	130	5,500	3,160	154	3.73
1924 Fiat Roots (S)	8	60	87.5	146	5,500	3,160	169	4.19



Cross section of 1923-5 Sunbeam 2-litre engine. Scale 1 : 4





Right : The mounting of the Wittig vane-type blower for the 1923 Fiat engine is shown with (above) details of the blower itself.

The figures for the engine as first designed make an interesting contrast with those of the Mercedes engine. On the latter Paul Daimler and Ob. Ing. Gros used supercharging, to raise the h.p./sq. in. by some 50 per cent, whereas on the Fiat the engineers responsible (Fornaca, Cavalli and Zerbi, Cappa having resigned) were rewarded by an increase in specific output of only some six per cent, the gross output increasing by only ten per cent despite the use of substantially enlarged piston area.

It is easy to see from these figures why the supercharged Fiats at Tours were but very little faster than their unsupercharged rivals and these somewhat disappointing results can probably be ascribed to the poor adiabatic efficiency in the supercharger leading simultaneously to high power consumption in the blower and (probably) very high temperature of the pressure air supplied to the carburetter. Additionally, this early vane-type blower, which had proved reliable on the test-bed and at trials on the Monza track, suffered mechanical failures when subject to the harder tests of Grand Prix racing on a dusty circuit with many violent changes of engine speed. It is therefore scarcely surprising that it was quickly replaced by a Roots type, the naturally high mechanical efficiency of which more than offset the absence of pre-compression within the blower casing at contra pressures of up to 10 lb./sq. in. Still further to improve the overall efficiency a somewhat elaborate inter-cooler was placed between the blower and the carburetter so that mixture was finally delivered to the cylinders at a boost of 8.5 lb./sq. in. and 54 degrees C. with the engine running at peak power.

These developments took place between the French and Italian Grands Prix of 1923 and the same engine and blower combination was retained throughout the 1924 season. It will be noticed that in its second manifestation b.m.e.p. was increased by 16½ per cent compared with the earlier unsupercharged engine and this may be considered a somewhat disappointing result in view of the comparatively high supercharged pressure. If, however, we compare b.m.e.p. at the same crankshaft speed we find that there is an increase from 145 lb. to 179 lb. with a blower pressure of 8.2 lb./sq. in., that is to say, an increase of 23 per cent in a b.m.e.p. following a rise in manifold pressure from 1.0 to 1.57 ata. Examination of the output curves makes it clear, however, that the peak

of the b.m.e.p. curve was at the comparatively low speed of 4,000 r.p.m. at which the excellent figure of 187 lb./sq. in. was realised with an absolute manifold pressure of 1.5 ata. It is therefore fairly clear that this engine suffered from poor breathing despite the use of large diameter valves, and this was probably due to somewhat abrupt bends in the inlet ports coupled with inadequate inlet valve opening periods. In this matter the curves reproduced in Chapter XIV should be studied.

Despite these technical criticisms the effect of supercharging on road performance was very marked. It is claimed that the fully developed six-cylinder engine would give a road speed of 112 m.p.h. whilst the blown type gave 124 m.p.h. in its first form and 136 m.p.h. when fitted with a Roots blower. These gains in speed are all rather higher than one would expect on the basis of the cube root law, but there is no question that following the increase in engine output over a wide band of the speed range the speed at Monza with the Roots blown car in 1923 was five per cent faster for a lap than that of the 1922 unsupercharged model. As the overall annual increment in road speed lies between one and two per cent, a gain of this order in one year was both abnormal and decisive.

The technical details of the Fiat engines of 1922-7 may be found in Chapter XIV, and the influence of their success on the design practice of other companies was immediate.

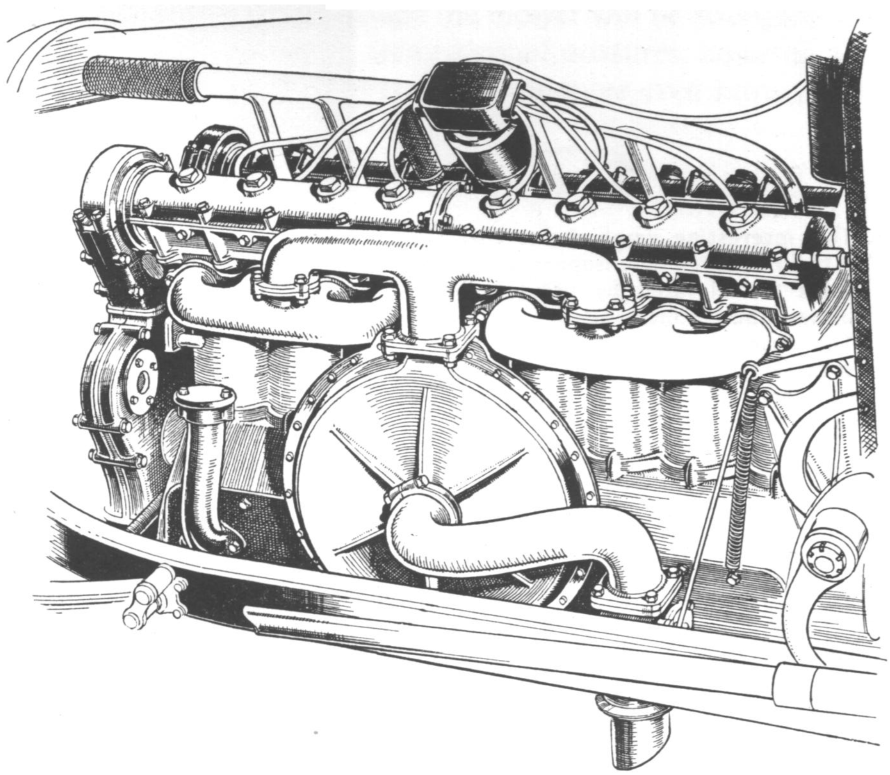
By the Spring of 1924 not only Sunbeam but also the Alfa Romeo Company were running a supercharged 2-litre car which largely followed Fiat principles. This, the celebrated P2 model, which had a useful racing life of over five years, also had a constantly driven Roots-type blower driven directly from the nose of the crankshaft and although an inter-cooler was not used, the pressure air was supplied to the carburetter through a large ribbed aluminium pipe.

As already mentioned, the first successful supercharged racing car was built in the U.S.A. and used a centrifugal-type blower. The determination of design by tradition is one of the more remarkable features of automobile history and explains in part that when supercharging was at last revived in the U.S.A. for the Indianapolis races a centrifugal blower was employed. The 2-litre Duesenberg which ran in 1924 used an 8 in. impeller mounted at right angles to the crankshaft on the inlet side of the engine, a short cross-shaft passing between cylinders Nos. 4 and 5, connecting to a right-angle bevel drive joined in turn to a shaft running backwards to the timing gears at the front of the engine. The overall gear ratio was such that the impeller was driven at eight times engine speed, so that at 5,000 r.p.m. the tip speed of the impeller was over 1,300 ft./sec.

Rotor tip speed is of vital importance in centrifugal blowers, for unlike the positive delivery type, pressure is built up as a conversion from velocity, and, as a direct consequence, the supercharge produced by a centrifugal blower is far more dependent on engine speed than it is with a positive displacement type, such as the Roots.

Some examples are worth quoting. With the positive displacement type delivery per revolution increases with rise in the speed since the slip loss (or leak) through the required clearances forms a diminishing fraction of the total volume of air pumped per minute. Empirically the change will be as from, say, 65 per cent volumetric efficiency at 2,500 r.p.m. rising to 80 per cent at 4,000 r.p.m. and constant after. If,

therefore, a supercharger with a theoretical swept volume of 2 litres per revolution be geared directly to the crankshaft on a 2-litre car the net volume delivered at 1,000 r.p.m. will be $\frac{2 \times 65}{100}$ which equals 1.3 litres, whereas at 4,000 r.p.m. it will be $\frac{2 \times 80}{100}$ which equals 1.6 litres. In round figures, therefore, the boost will vary as between 4½ lb. (1.3 Ata) (in the lower part of the speed range) to 9 lb. (1.6 Ata) and will be constant between, say, 4,000 and 5,500 r.p.m.

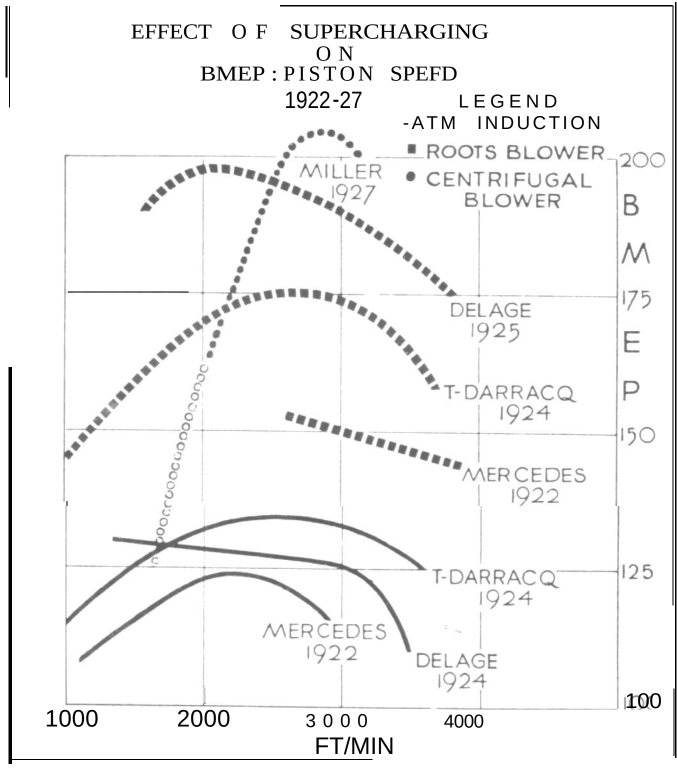


The drawing shows the 1924 Duesenberg engine which won the Indianapolis Race of that year : this engine was one of the first to suck mixture from a carburetter mounted on the intake side of the blower, a practice which has since become universal.

The centrifugal blower behaves differently. Some curves published by the A.C. Sparking Plug Co., relating to Miller engines, show that a 9lb. boost at 4,000 r.p.m. rose to 18 lb. at 6,000 r.p.m. and calculations prove that at 3,000 r.p.m. the blower would provide little or no positive pressure.

Hence applying a centrifugal blower to an engine results in a radical revision of the b.m.e.p. and torque characteristics, there being little gain at low speeds and a very substantial step-up at the top of the power curve. By contrast, with a Roots blower, particularly if it is driven at more than engine speed, the b.m.e.p. curve is lifted up along its entire length but retains basically the same form as on an unblown type. Some graphs show this clearly, a particularly interesting comparison being between the b.m.e.p. figures for the 1925 Delage and for the Miller. At over 2,500 ft./min. (circa 5,000 r.p.m. on both engines) the Miller is superior, but below this speed the curve falls away very rapidly indeed. In U.S.A. track racing, where the cars run at virtually constant speed, the centrifugal blower is admirably suited for it is light, compact, presents no lubrication or mechanical friction problems and will give high pressures with excellent efficiency. By contrast the Roots blower becomes increasingly inefficient with contra pressures above 10 lb. (1.6 Ata), and the alternative vane types are bulky and present many mechanical difficulties. However, the sensitive relation between r.p.m. and delivery characteristics of the centrifugal blower put a car so equipped

at an almost hopeless disadvantage in road racing where there are wide variations in engine speed, whereas the good pumping of the Roots type, particularly when driven at over engine speed, is of the greatest value in sustaining m.e.p. and torque at the low end of the r.p.m. scale. For these reasons the use of the centrifugal blower



This interesting graph shows that the B.M.E.P. curves of unsupercharged engines are elevated by using a Roots blower but remain similar in shape. The characteristic curve with a centrifugal blower has a pronounced peak and falls off badly at low engine speed.

by Duesenberg (afterward followed by Miller and the other leading U.S. constructors) effectively debarred American cars from becoming serious competitors in European Grand Prix racing and negatived any possibility that the 1921 French Grand Prix success could be repeated after 1923.

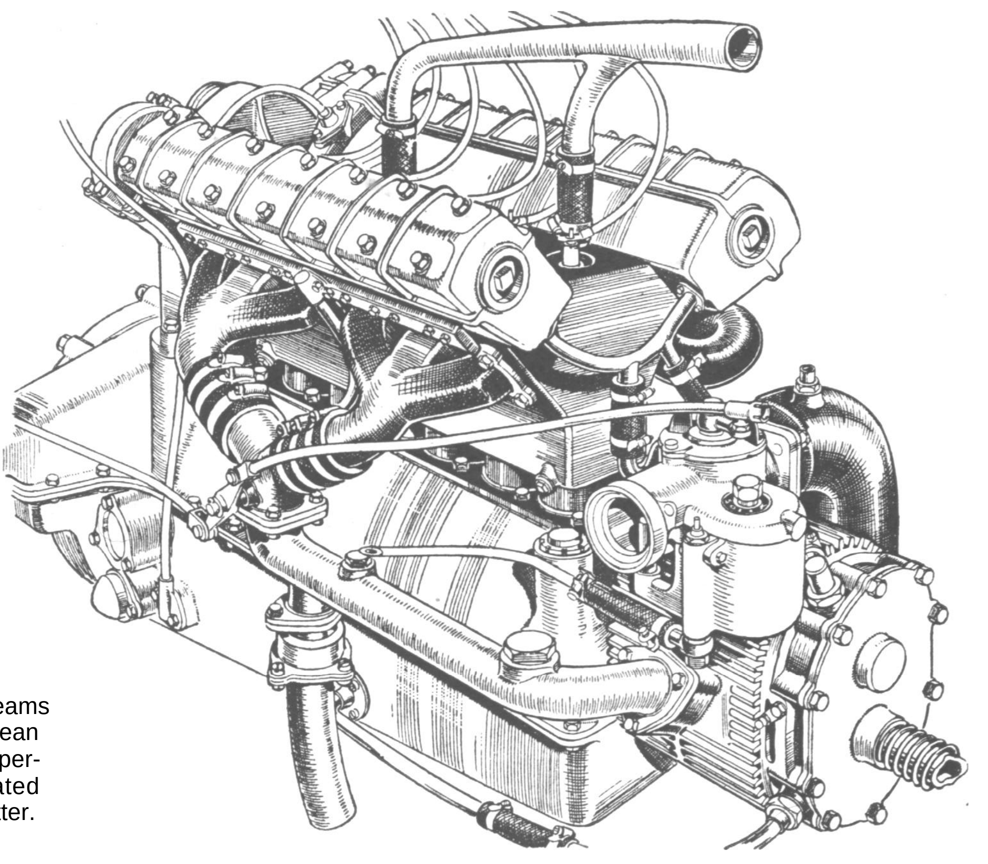
In one detail Duesenberg made a most useful contribution to the art of supercharging, for the 1924 car initiated the supply of mixture to the blower, and thus of fuel and air under pressure to the inlet manifold. This apparently simple change (which may well have had its origin in the accident of practical convenience) had far-reaching results. The mechanical carburation imparted to the mixture ensured better distribution between the cylinders, and, perhaps even more important, the latent heat of vaporisation of the fuel could be used to limit the temperature rise in the blower and the intake manifold. This last-named factor led in turn to the widespread use of alcohol fuels, although with moderate boost pressures the anti-knock qualities of alcohol blends were not seriously needed.

It is sometimes assumed that raising the manifold pressure by, say, 50 per cent is equal to raising the compression ratio in like proportion (from, say, 6 : 1 to 9 : 1), and that fuel quality must be correspondingly adjusted but a more realistic relation is given by the formula (O. Thornycroft, *The General Question of Supercharging,* I.A.E. Proceedings, Vol. 30) :

$$R_2 = R_1\left(P_1/P_2\right) 0.6$$

The experience of the writer gives a lower power–0.5, on which basis 50 per cent boost on a 6 : l ratio is, from an anti-knock viewpoint, equal to 7.75 : 1 running unblown. From this it will be seen that it is quite possible to cope with all normal supercharge pressures by adding reasonable quantities of Tetra-Ethyl-Lead to straight petrol, if detonation is the only problem, and that the special virtues of alcohol blends are a result of their high latent heat of evaporation.

With a 60 per cent adiabatic efficiency in the blower and 10 lb.boost (1.66 Ata) the delivery temperature with air alone passing through the blower will be 80 degrees C., and with petrol added it will be 60 degrees C. By using alcohol mixtures, however, the ingoing charge can readily be reduced to the ambient temperature, or even below, with



The 1924 G.P. Sunbeams were the first European engines to use a supercharger that aspirated through the carburetter.

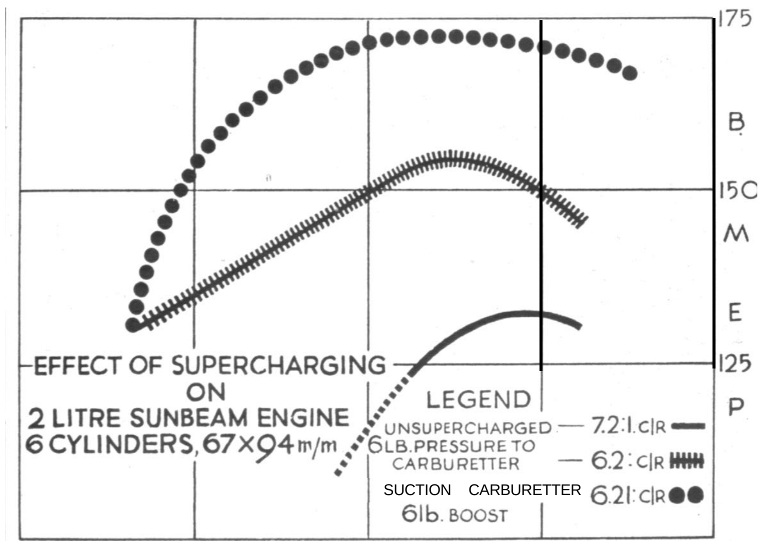
a substantial reduction in power required to drive a supercharger, a gain in weight of charge delivered to the engine and a reduction in temperature of internal danger areas, such as the exhaust valves and sparking plugs.

Moreover, although with petrol enrichment of the fuel : air ratio beyond 1 : 12 leads to a substantial loss in power, extremely strong mixtures of alcohol (of the order of one part fuel to four parts of air by weight) can be fed into engines without power loss. Developments along these lines were, however, to come much later in the history of the supercharged engine ; in the early years, with which this chapter is concerned, one of the most significant developments was the combination by Sunbeam of the Roots-type blower with a carburetter on the induction side.

From the technical viewpoint the supercharging of the 2-litre Sunbeam engine in 1924 is of two-fold interest. Because it was an existing design it is possible to make

direct comparison between unblown and blown outputs ; because experiments were made with the carburetter placed both fore and aft of the blower we can examine the effect of this change.

By the courtesy of J. L. Wyer, Esq., sometime member of the Sunbeam Experimental Department, it is possible to provide complete information on these experiments. The unsupercharged engine at its highest point of development, running with a 7.3 : 1 compression ratio, developed 102 h.p. at 5,000 r.p.m., corresponding to 134 b.m.e.p. at 3,100 ft./min. This was almost the peak of the m.e.p. curve, the figure falling off sharply so that at 3,500 r.p.m. only 124 lb. was realised. The application of a supercharger elevated the b.m.e.p. figure to 140 lb. at 1,000 r.p.m., and with the carburetter placed on the pressure side of the induction system, the m.e.p. curve rose gradually and in a straight line from this figure up to 150 lb. at 3,500 r.p.m. It then flattened, declining to 146 lb. at 5,200 r.p.m. corresponding with a maximum power of 115 b.h.p.



Bringing the carburetter on to the suction side of the blower transformed the characteristics. The m.e.p. curve rose rapidly in the lower part of the engine, speed reaching 150 lb. at 1,400 r.p.m., 170 lb. at 2,800 r.p.m. and peaked at 178 lb. at 4,500 r.p.m. At 5,500 r.p.m. the figure realised was 170 lb., corresponding with 138 b.h.p.

The b.m.e.p. curves reproduced in graphical form are related to piston speed so as to make them directly comparable with previous (and later) facts, but the advantages of supplying mixture to the blower are clear whatever system of presentation be adopted. It is scarcely surprising that following the pioneer work of Duesenberg and Sunbeam in 1924 the practice of placing the carburetter on the suction side of the blower became uniform with the solitary exception of Mercedes-Benz who, somewhat obstinately, clung to the pressure air arrangement until the mid-summer of 1937. Generally speaking, however, the principles of supercharging were thoroughly established in the brief space between the French Grand Prix races of 1923 and 1924, and there were no great developments during the ensuing ten years.

CHAPTER THIRTEEN

1924-5 – Fixing the Type

IT has been remarked in the early chapters that the year 1925 is remarkable for being the first occasion in which a driving mechanic was not required. The regulations, however, still prescribed two-seater bodies, and although frontal area was slightly reduced by the absence of the mechanic's head, left shoulder, and arm, the change cannot sensibly have modified circuit performances. The three years 1923-5 saw the evolution of the classic type of racing car ; after some twenty years of development the type was, as it were, fixed and it is, therefore, of value to make a general summary of the state of the art at this time.

A notable development during this period was a steady increase in weight, although the engine capacity remained constant. In 1922 the winning Fiat had a wheelbase of 8 ft. 2½ in. and weighed approximately 14 cwt. In 1923 the eight-cylinder Fiats weighed nearly 15 cwt., and the unsupercharged Sunbeams turned the scales at the exceedingly low figure of 13.3 cwt., but by 1924, when Sunbeams developed new chassis to take the blown engine, having torque tube drive and a longer wheelbase (8 ft. 6 in.), the weight went up to 16 cwt., with Alfa Romeo about half-a-cwt. lighter. Delage and Bugatti, running unsupercharged, were much lighter, about 14 cwt. only.

Nevertheless, due to the greater power developed by the blown engines, the power-to-weight ratio figure very much favoured the latter type. In assessing this figure we should really take the car in running trim, i.e., with fuel and crew. If we do this we find that the 1922 Fiat had about 102 b.h.p. per ton, the 1924 Sunbeam 150 b.h.p. per ton, and the 1925 (driver only) Alfa Romeo 180 b.h.p. per ton ; in other words, in three years the power-to-weight ratio increased by 77 per cent.

The power per square foot of frontal area also rose from about 7½ h.p. on the Fiat and 13½ h.p. on the Sunbeam, to about 17 h.p. on the twelve-cylinder Delage of 1925. On this basis one would expect the maximum speeds of the cars to be of the order of: Fiat, 100 per cent ; Sunbeam, 121 per cent ; Delage, 133 per cent. As we know that the latter car had a timed maximum over the kilometre of 134 m.p.h., it follows that the calculated maxima would be : Sunbeam, 124 m.p.h. ; Fiat, 102.5 m.p.h. ; we know that under neutral conditions these figures are very close to the truth and that they correlate well with the estimates derived from average indexes.

A study of the data table shows that power per litre, which is, after all, the determining issue under a capacity formula, was more than doubled during the course of three years. B.M.E.P. was elevated by nearly 50 per cent and power per square inch of piston area raised by 66 per cent, and although piston speeds did not increase very greatly, r.p.m. were raised from approximately 5,000 to as high as 7,000 on the Delage by reducing the piston stroke. The stroke : bore ratios varied between 1.4 and 1.55 : 1, in place of the 1.72 : 1, which was so popular during the 1920-21 period.

Compression ratios changed but little, being about 6 : 1 on the earlier engines and 7 : 1 on the 1925 types. Using atmospheric induction one would, from the foregoing considerations, expect maximum horsepower to increase from the 92 b.h.p. of

the 1922 Fiat up to about 125 b.h.p. for the Delage, i.e., by 40 per cent. It is, therefore, evident that 40 per cent of the 100 per cent gain in power per litre may be credited to mechanical improvements and increase in piston area and 60 per cent to supercharging. This in turn implies a supercharge pressure of between 7.5 to 9 lb. per square inch.

Conservative ideas on valve timing were held by practically all designers. On the 1922 Fiats the inlet valve opened on top-dead-centre and the exhaust valve closed only 10 degrees after top-dead-centre, but on the 1924 supercharged Sunbeams, developed from the Fiat, the inlet opening was 10 degrees before top-dead-centre, and the exhaust 15 degrees after, giving an overlap of 25 degrees.

The period under review marks the end of petrol-fuelled racing engines, for as compression ratios were increased in 1922 and 1923 from 6 : 1 up to 7 : 1 it became necessary to add liberal percentages of benzole to the petrol. With supercharging it also became desirable to add alcohol and, although the earlier blown engines used something like a 40 : 60 petrol-benzole mixture, later types ran on about 40 : 40 : 20 petrol-benzole-ethyl alcohol.

In construction the V12 Delage stood alone, for the straight-eight type was dominant throughout. Design conformed very much to a pattern in which the crankshaft ran on ball or roller bearings and was of one piece, the connecting rods also having roller bearings and split big ends and roller cages. Pressure lubrication through the crank was general, as were two valves per cylinder, inclined at a very wide angle around 100 degrees. In other words, the Fiat concept replaced that of Peugeot.

In the previous chapter certain details particularly relevant to the supercharging of the 1923 Fiat engine were set out, and although this eight-cylinder type 405, as it was called, closely resembled the six-cylinder type 404, the weight, surprisingly enough, was actually reduced from 397 lb. to 375 lb.

As before, the crankshaft (which was formed in two halves) ran in roller bearings but the diameter of both the main journals and the crank pin was increased from 40 mm. to 44 mm. The use of roller bearing big ends with split big end caps and cages was continued but the connecting rods made, as previously, from nickel chrome steel, were substantially shortened both absolutely and relatively, whereas the 1922 engine had rods 250 mm. between centres (stroke x 2.23), the 1923 type rods were 165 mm. between centres, i.e. stroke x 1.89.

The fabricated steel cylinders were grouped in two pairs of four, and a detail point of interest is that the plug bosses were given internal circumferential fins and the masking hole was elongated to 18 mm. on the longitudinal axis of the engine. As before light alloy pistons were separated from the bores by bottom seating rings and the valves gave an included angle of 100 degrees. On the eight-cylinder the camshafts were driven by two very short shafts at an angle with a train of three spur wheels running up from the back of the crankshaft.

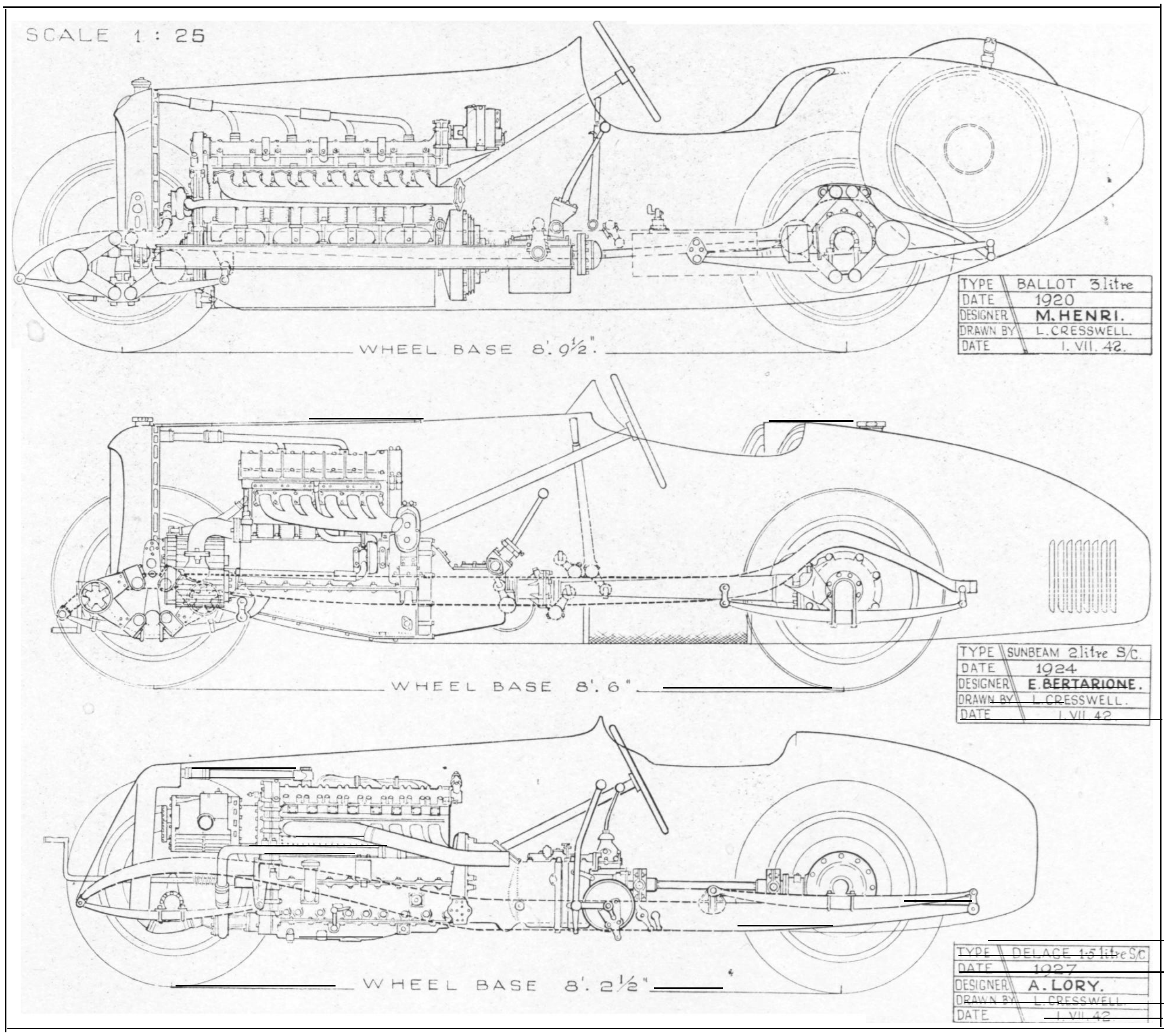
The use of split cage roller bearings and big end was a feature which has subsequently been used by a number of other constructors, and in view of the fact that the Fiat steel cylinder construction was definitely taken over from Mercedes, it is not uninteresting to note that the latter company were also using split cage roller bearings in their 1922 racing engines, which were on the drawing-board in 1921.

Bugatti was consistently exceptional, with engines having three vertical valves per cylinder, two inlet and one exhaust, plain big ends, and jet-type lubrication to them.

For the journals he employed a centre ball bearing on his three-bearing types, which had solid crankshafts, and five roller bearings on his later models, which had built-up crankshafts held together by taper keys.

The cooling on the majority of the engines was exceedingly good, being facilitated by the wide angle of the valves ; by contrast, Bugatti, with his vertical valves, found himself with what may be best termed iron-cooled head, although it must be admitted that performance did not seem to suffer greatly thereby.

In chassis design, one sees universal employment of four-speed gearboxes and typical ratios taken from the Sunbeam car give speeds for the indirect gears of about 90 m.p.h., 65 m.p.h. and 45 m.p.h.



Braking systems showed exceedingly little change, 14½ in. brake drums, giving a brake area of about 330 sq. in. per ton of car weight, being almost standard components. These were operated at high unit pressures between the brake lining and the drum, and this in turn involved a friction servo mechanism driven off the rear and off the gearboxes. Movement of the brake pedal applied a middle brake system running at one-thirtieth engine speed and the reaction was used to apply the normal brake shoes.

Frames, springs, shock absorbers and steering mechanism remained basically unchanged; in fact, the only chassis trend worthy of note is a gradual acceptance of the view that the rear springs should be relieved from torque either by torque tube drive or by separate radius arms, as employed by Bugatti. The latter designer, incidentally, was one of the few who omitted the brake servo motor.

Chassis design to some extent stagnated, but engines made greater strides in the two years 1924 and 1925 than they have done at any similar period subsequently. On twisty circuits, which put a premium on brake stability and cornering power, the 1925 2-litre cars were slower than the 1½-litre types which followed them, but on really high speed circuits they maintained their superiority for an astonishing length of time; it was, for instance, six years before the lap record at Monza, put up by the P2 Alfa Romeo in 1924, was beaten.

It was this disproportion between engine power and maximum speed on the one hand and inadequate chassis design on the other which led to the abandonment of the 2-litre formula in the interests of safety and the introduction of a capacity limit of 1½ litres for the period 1926-7, which will be reviewed in the next chapter.

CHAPTER FOURTEEN

The Nemesis of Power

THE 1½-litre limit for the racing seasons 1926 and 1927 accelerated the trend towards engines of high r.p.m., high piston speed, large piston area in relation to capacity, and led to complicated construction.

From the point of view of power per litre, the results were very striking, and were not, in fact, exceeded during the ensuing ten years, but the comparative complexity of the high speed, eight-cylinder, l½-litre engines was, however, their undoing in the first phases of the new formula. In 1926 neither the Talbot nor Delage cars were able to do themselves justice, the honours going to Bugatti, who adopted the comparatively simple expedient of reducing the bore and piston area of his 2-litre engines and compensating for these changes by adding a supercharger. Exact statistics on the output of the 1926 Bugatti engine are unobtainable, but it is likely, on first principles, that it did not develop over 105 b.h.p., equivalent (with cylinder dimensions of 52 x 58 mm.) to 4.0 b.h.p. per square inch of piston area, and a b.m.e.p. of approximately 150 lb. at 6,000 r.p.m. The gross output available was thus reduced by some 60-70 b.h.p. compared to the 2-litre Alfa Romeo and Delage cars, and lap speeds on fast courses fell in sympathy. For example, at Monza, the Bugatti lap of 98.3 m.p.h. compares with the best figure of 104.24 of the Alfa Romeo, a drop of roughly 6 per cent. Using our established guide of average speed, varying with the sixth root of power per square foot this implies power deficiency of about 33 per cent. On a slow course such as San Sebastian the reduction in circuit speed was only 2.5 per cent.

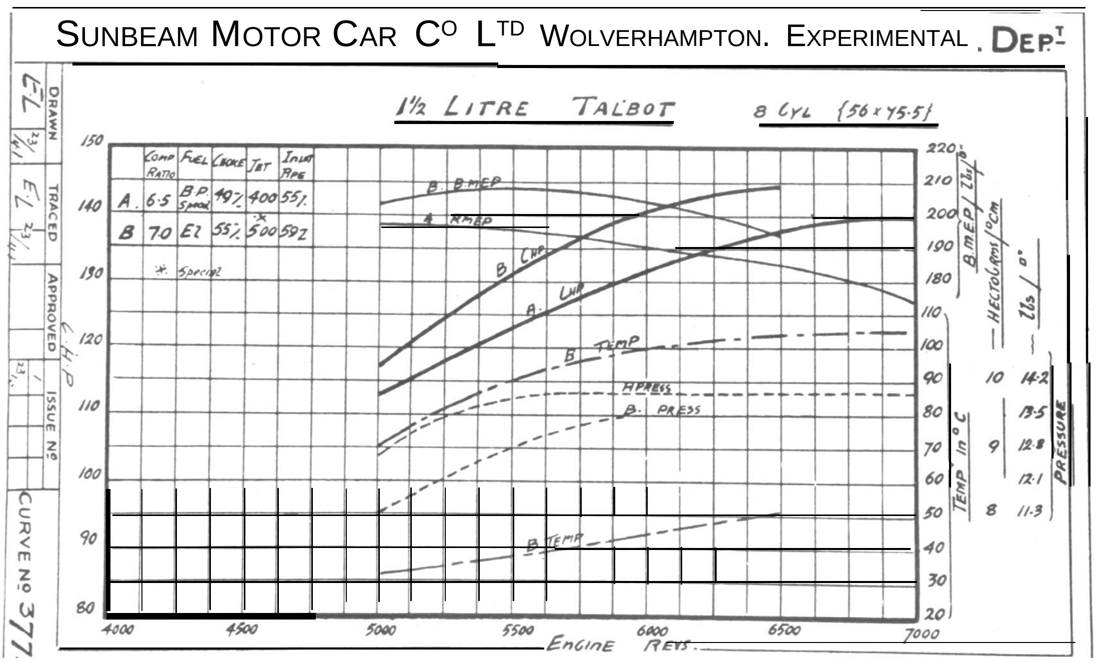
It must, however, be admitted that the three Bugatti wins in 1926, that is the French Grand Prix, the European Grand Prix and the Italian Grand Prix, were due more to the unreadiness of the opposition than to any superiority of Bugatti design.

Technically, the principal interest in the l½-litre formula lies with the Talbot and Delage cars, and neither of these were in proper running condition until 1927. Both engines had almost identical bore, stroke and piston areas, but the designers (Bertarione and Becchia for Talbot, and Lory for Delage) approached the problem of developing maximum horse power per litre from substantially different viewpoints. Lory built a straight-eight version of the Vee twelve-cylinder Delage, running at the remarkably high piston speed of 4,000 ft./min., with moderate boost and b.m.e.p 1.47 (Ata), and 177 lb. per sq. in., respectively. The Talbot designers, on the other hand, accepted a limit of a little over 3,000 ft./min. piston speed, but took the boost pressure up to 1.92 (Ata), with a resultant b.m.p. of some 210 lb. sq. in.

By the courtesy of John Wyer, Esq., it is possible to reproduce an actual test curve of the Talbot engine, which reveals, not only the power output, but the extraordinarily interesting influence of alcohol fuel on boost pressure, manifold temperature and power output. The curves A reproduced were taken on a petrol-benzole mixture, whereas curves B relate to the use of a 40 per cent alcohol, 40 per cent benzole and 20 per cent petrol blend. When running with the latter, the compression ratio was raised by half a ratio, and the area of the jet increased by 56 per cent with a corres-

ponding rise in fuel consumption. This reduced the manifold temperature from 87° to 50°C., with a drop in boost pressure of about one-fifth of an atmosphere. Output rose from 137 to 144 b.h.p., and the mean effective pressure from 184 to 193 lb.

The Talbot engine was entirely characteristic of the times, and just as the 1½-litre Delage may be considered a logical development from the previous twelve-cylinder type, so the Talbot was an obvious extrapolation from the previous six-cylinder Sunbeam. It should perhaps be emphasised that although the 1½-litre formula was new in so far as Grand Prix Racing was concerned, this size had been in common use in Voiturette racing for the previous five years.



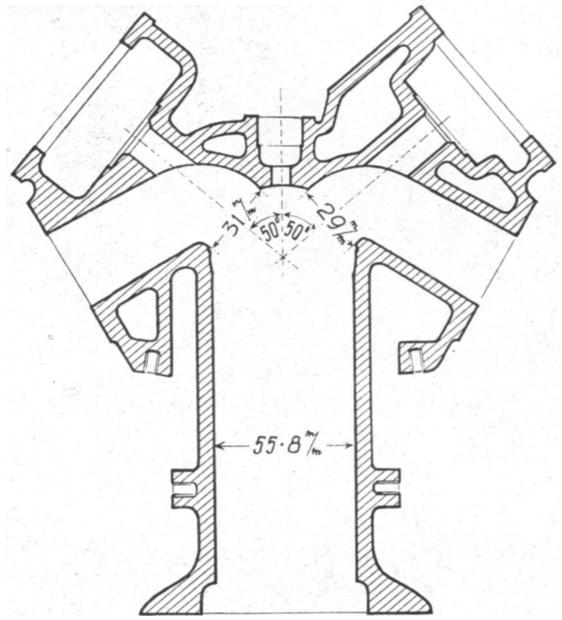
It is, therefore, of interest to make a comparison between the 1926-7 types and those of the same pedigree which immediately preceded them in the Stud Book.

It is especially valuable to analyse the difference between the best specimen of 1924, i.e. the Talbot-Darracq, and the 1927 Delage, for both of these cars were supercharged to about the same manifold pressure. The gain in m.e.p. in these three years was only 5 per cent, but the increase in horse power-per-litre was over 50 per cent, the source of the marked superiority of the Delage springing from an ability to run up to 8,000 r.p.m. and to hold 6,500 r.p.m. for long periods. This quality was derived in part from the use of eight cylinders in place of four, in part by raising the maximum piston speed to as much as 4,000 ft./min This figure was an exceedingly high one, which would have involved severe friction losses if the mechanical layout of the engine had not been devised with outstanding skill.

Although there is no reliable data available as to the relative efficiency of ball and roller bearings compared with plain bearings, there are good reasons for suspecting that the extra power derived from using the former is considerable at high rotational and piston velocities. Lory took no chance in this matter on the Delage, which had ball or roller bearings throughout, with the exception of the oil-pump spindles. Thus, the crankshaft ran on ten separate roller bearings, with eight roller big-ends. Each

camshaft was supported on eight roller bearings and the drive to both of them involved fourteen ball bearings. The blower made up a total of four more roller bearings and then the magneto drive notches up the score for ball bearings by a further half-score, making a grand total of sixty-two races of one sort or the other !

When one reckons that, in addition, the engine incorporated twenty-one gears, forty-eight valve springs and thirty-two piston rings, it becomes clear that the Delage Company were in no mood to let complications and expense in design or manufacture stand in the way of the best possible results. But all this effort would have been wasted if the design of the blower and cylinder head had not been so arranged that full advantage could be attained from the high engine speed potential.

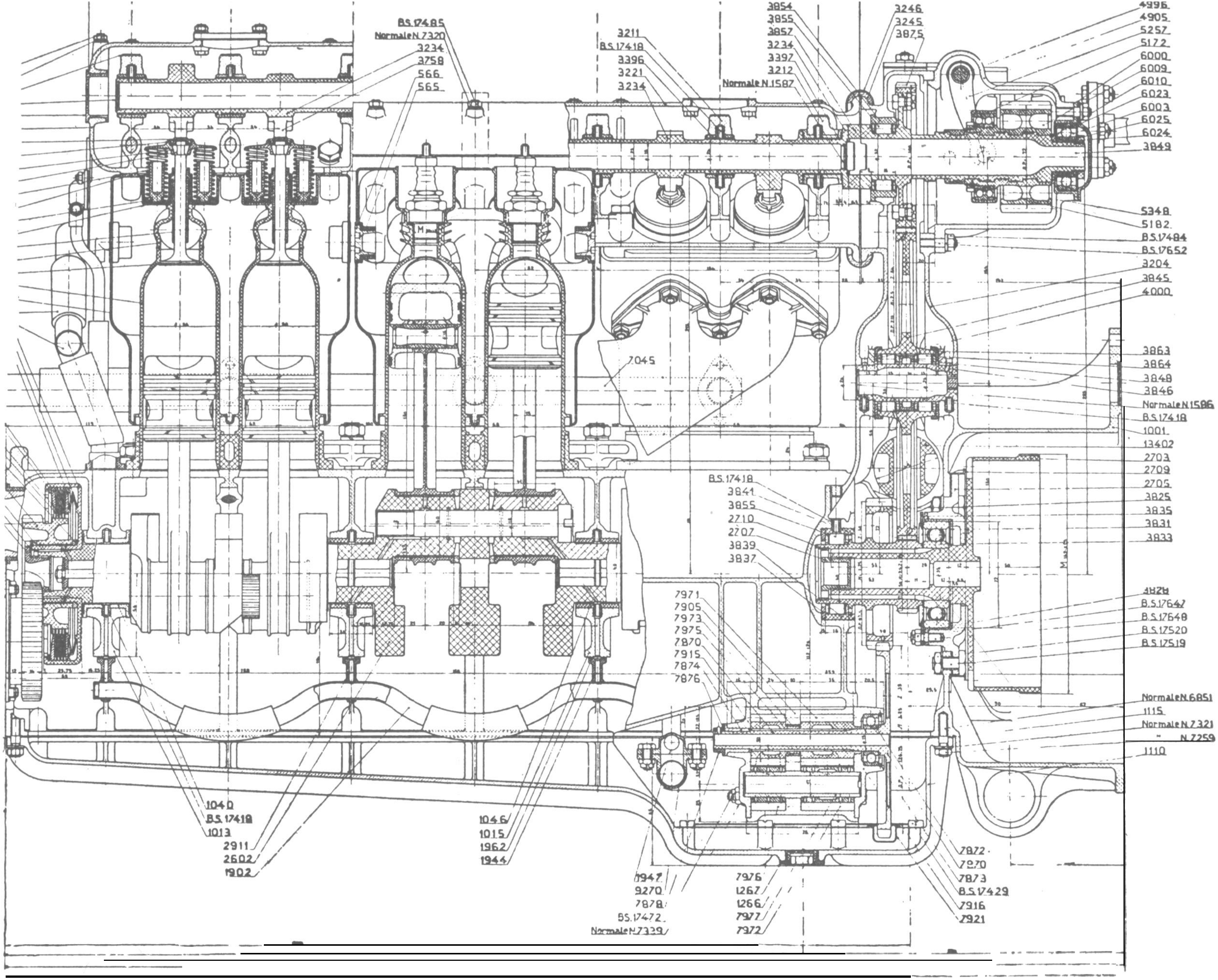


A detail drawing (Scale 1 : 3) of the 1927 Delage cylinder with two valves at an included angle of 100 degrees. The careful port shape and good cooling on the exhaust (right hand) side should be noted ; also the open walls later closed by steel plates.

As a cross-sectional drawing shows, the cylinders were most excellently arranged. The sides of the casting were left open so that one could be really sure that no sand from the foundry remained in awkward places, whilst the wide angle of the valves, and the intelligent disposition of the water spaces, made a model which subsequent designers would have been well advised to follow, but which all too often, unfortunately, they failed lamentably to do.

It is worth noting that the valves were inclined at 100°, and that the flow value was first-class as shown by the excellent figure of horse power per sq. in. of piston area, despite the comparatively low boost.

The steady increase in valve overlap which was the logical accompaniment to increased engine r.p.m. is worth noting. Taking intervals of two years, 1922, 1924 and 1926, and using as our examples the four-cylinder Aston Martin, four-cylinder Talbot-Darracq and eight-cylinder Delage, we find that the inlet valve was opened 3° after, 94° before and 18° before top-centre respectively. The exhaust valve in the same order closed 12°, 10° and 12° after top-centre. Thus overlap increased from 9° in 1922 to 19° in 1924, and 43° in 1926. The inlet opening period rose from 217° in 1922 to 234° in 1924 and 248° in 1926.



The double-six 1½-litre Fiat of 1927 had a built-up crankshaft with one-piece connecting rods, having very wide plain bearings, as shown in this 1 : 4 scale drawing. The crankshafts were geared together and the four overhead camshafts were driven by a train of gears at the back of the engine. The use of fins on the sparking plug bosses should be noted, also the multiple valve springs and the assembly of the steel cylinders into three groups of two each.

Let us consider in rather more detail the relations between the 1922 Strasbourg Aston Martin and the 1924 1.5-litre Talbot-Darracq. Both had four cylinders, and the difference in piston area was under 5 per cent, but the power per litre of the latter was nearly twice that of the former, although engine speed rose by only 20 per cent. The main gain was derived from a 60 per cent gain in m.e.p., the source of which is obvious, in that the latter engine was supercharged with 7 lb./sq. in. boost pressure. This by itself sufficed to raise the output to over 80 h.p. and the m.e.p. from 106 to 150 lb. per sq. in. and the small balance, not due directly to blowing, can be ascribed to improved inlet arrangements, for there is little doubt that the single large inlet-valve on the Talbot-Darracq had a substantially better flow-value than the two inlet-valves on the Aston Martin.

The success of four-cylinder, l½-litre engines up to 1925 did not lessen the essential need for power units with basically greater piston area for the l½-litre formula 1926-27. On this score, Bugatti was in a favourable position for he had his five bearing, 2-litre, straight-eight which had run in the 1925 Grand Prix, and by varying bore and stroke he was able to use the same block castings irrespective of whether the capacity was 1.5, 2.0 or 2.3 litres. The smallest size was, of course, definitely over-valved, and, as a blown type, gave much the lowest figure of h.p. per inch of valve area. It had additionally a very moderate total power, due in part to the modest boost pressure, in part to the rather poor breathing conditions resulting from the use of two small inlet and the one exhaust valve all placed vertically in the cylinder head.

From a mechanical point of view the Bugatti could have been supercharged at a much higher pressure, and the power of the 1927 type (60 x 66 mm.) could have been raised without much difficulty to the 150 b.h.p. mark if 4.25 h.p. per sq. in. of piston area had been forthcoming. Owing, however, to the well-known allergy between Bugatti cylinder heads and the cooling fluid, it is doubtful whether the casting would have remained in one piece very long if so much power had been expected, and it had always been le Patron's policy that his racing cars should not break down, even if they were slower than the other starters. But with a single-cam vertical-valved engine Bugatti could scarcely hope to compete in speed with Delage, quite apart from other aspects of the matter, such as Bugatti's continued use of a two-seater body with the driver mounted above the propeller shaft, and consequent comparatively big frontal area and moderate h.p. per sq. ft. Hence from a strictly engineering point of view the only possible challengers to the Delage were the eight-cylinder Talbots (which were in fact, just as fast, and could have been made just as reliable) and (potentially only) from the experimental two-stroke Fiat which was never raced and the " double-six " which appeared only once.

The former was laid down in 1925 after the announcement of the A.I.A.C.R. that a I½-litre formula would be in force for the years 1926-27, and was given the type number 451. The design was the responsibility of Zerbi, Treves and Sola and, as may be seen from some drawings, it was an opposed piston two-stroke with geared crankshafts, being arranged so as to stand in the chassis with one crank above the other. The standard Fiat practice of roller bearing crankshaft and big ends was employed and with a bore and stroke of 52 mm. by 58.5 mm. the l½-litre capacity limit was attained with six-cylinder bores and 12 pistons. A Roots type blower was mounted on the nose of the crankshaft and driven at engine speed delivering pressure air to the carburetter at the modest boost of 5¼ lb./sq. in. (1.37 ata) to the inlet manifold which was connected

to a series of ports uncovered by the upper pistons. The exhaust ports were correspondingly uncovered by the lower pistons and advantage was taken of the separate crankshafts to give the exhaust crank a 21 degree lead in relation to the inlet crank. This resulted in the exhaust ports being opened 36 degrees before the inlet ports and closing 6 degrees before the inlet ports were covered, the inlet ports thus being opened for 140 degrees and the exhaust for 170 degrees. In this engine the practice of using bottom seating rings was abandoned.

Although over 150 h.p. was obtained the engine suffered from two weaknesses inherent to the type. The first of these was the comparatively short duration of the inlet port opening (little more than half the angle available for the conventional four-stroke) and the second the fact that all the exhaust gases were swept over one set of pistons. Despite the use of oil cooling for the exhaust pistons there was very rapid erosion around the ring bands, this perhaps being aggravated by the somewhat weak mixtures used which resulted in a consumption of only 0.83 lb./h.p./hr. The designer thereby denied himself the advantages of internal cooling which he might have had by increasing the alcohol content of the fuel and accepting double the rate of fuel consumption.

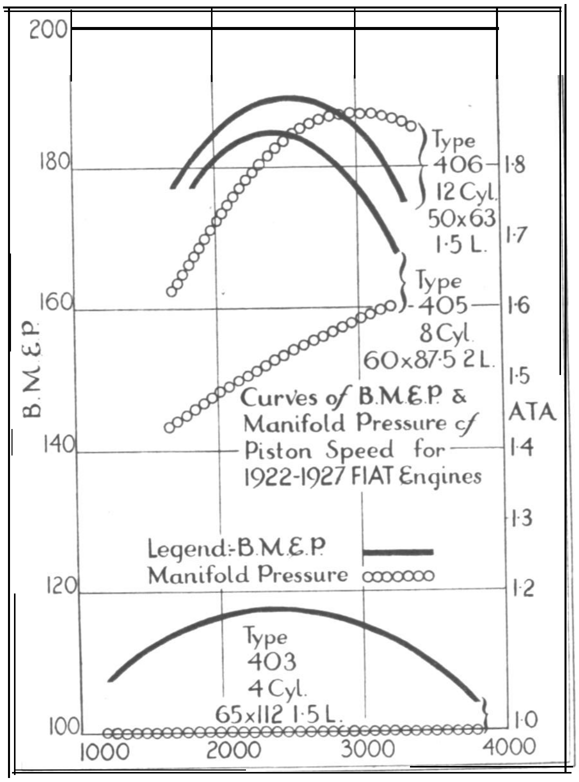
Development work on this engine was continued through 1926 but when it became apparent that the type was not going to be a practical proposition for the I½-litre formula an alternative double-six was quickly designed, and built during 1927. This, the type 406, had two crankshafts placed side by side and geared together, there being two rows of six vertical cylinders, with a bore and stroke of 50 mm. x 63 mm., placed side by side. Fabricated steel cylinders were built up in pairs of two, but although the pistons continued to be separated from the bores by the rings there were now two pairs of rings placed in each of the three grooves.

A major change in construction of this engine was the use of plain main and big end bearings in place of the previously employed roller bearing type, and to emphasise a change of heart in the design department the eye of the big end was now made in one piece with a built-up crankshaft of the Hirth type. Both crank pins and main journals had a diameter of 40 mm. and whereas the main bearings were 30 mm. wide the big ends were no less than 41 mm. wide. The four camshafts on this engine were driven by a train of gears and by virtue of the layout there was an exhaust manifold on the outer side of each block, the Roots blower delivering to two inlet pipes running between the cylinder blocks.

Valves 30 mm. in diameter were used with a lift of 7 mm. and although the general arrangement of the engine would seem to impose a severe weight penalty, in fact it turned the scale at only 381 lb. and was eventually developed to give 187 h.p. at 8,500 r.p.m. A more normal figure showing a peak of 160 h.p. at 8,000 r.p.m. with a boost of 12½ lb./sq. in. (1.88 ata) is taken as a basis of some curves relating manifold pressure and b.m.e.p. in relation to piston speed for some engines raced in 1924 and 1927, i.e., the 2-litre eight-cylinder 60 x 87.5 mm. with Roots blower, and the twelve-cylinder Type 406 described above.

It will be noted that the general shape of these curves is similar to those reproduced in Chapter 12 but shows far more rapid falling-off than does the eight-cylinder Talbot, a significant point in this connection being that whereas the Fiat engines with pure air pumped into the carburetters showed final temperatures of the ingoing charge

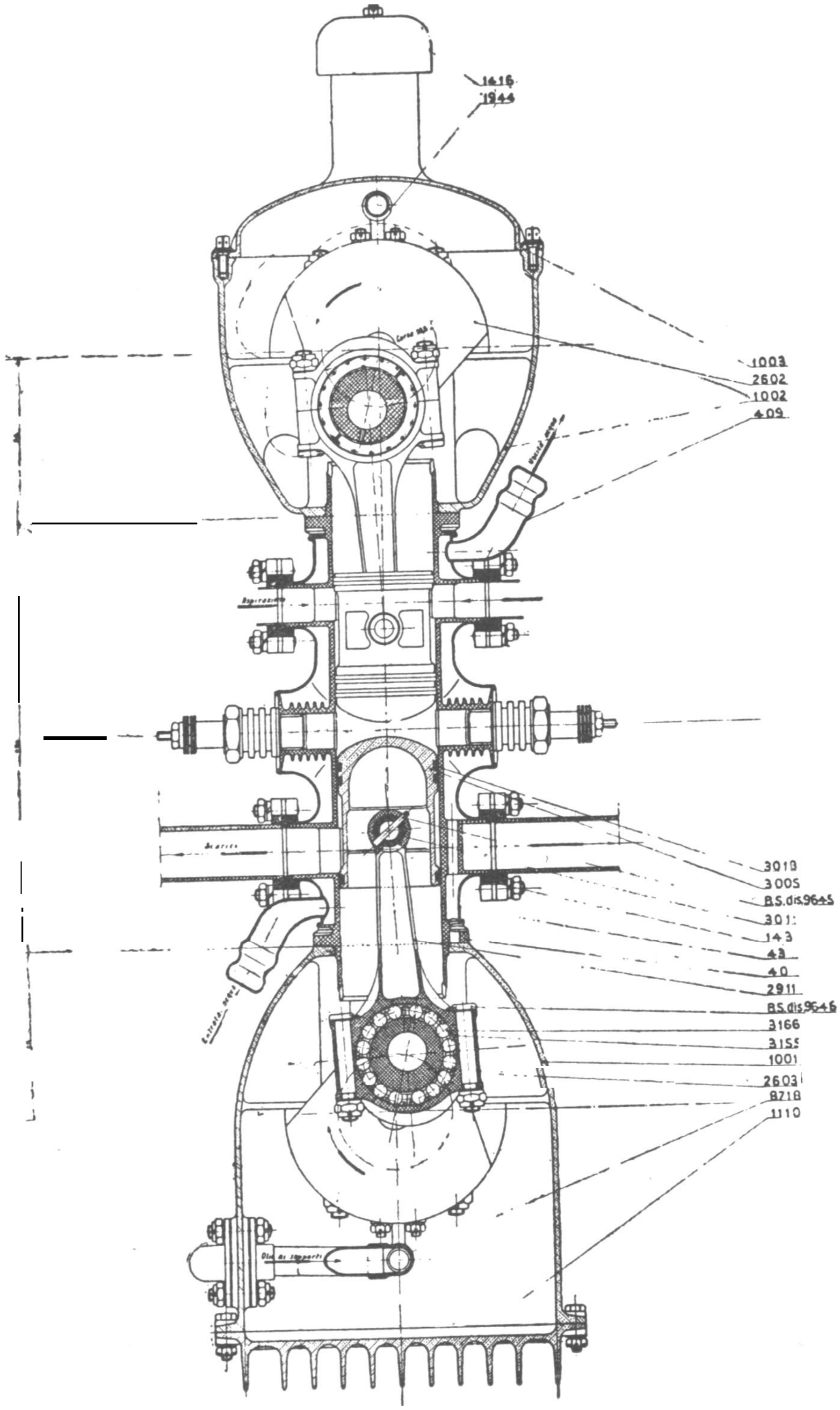
of 54 degrees C. at 1.6 ata. for the 2-litre, and 72 degrees C. at 1.88 ata. on the l½-litre, the Talbot did not exceed 50 degrees C. at 1.92 ata. There can indeed be no question but that the German and Italian method of feeding pressure air to the carburetter was inferior to the American and British practice of aspirating the mixture, even with the limited manifold pressures of the middle ’20s. Despite this, the fact that the twelve-cylinder Fiat engine had 20 per cent more piston area than either the Delage or the Talbot of equal capacity gave it an appreciable superiority in sustained power output and in maximum speed, although, here again, the makers’ claim of 149 m.p.h. is some 10 m.p.h. higher than one would expect, even with the highest quoted output of 180 h.p. As this car made only one racing appearance it is almost impossible to relate it to the the other more established vehicles, and one can only say that in the engine design it challenged the Delage as the prime example of power per litre sought regardless of mechanical complexity and cost.



The development of brake mean effective pressures in relation to piston speed and supercharge pressure is shown in these curves, which illustrate the very big gains made between 1922 (as represented by the 6-cylinder U/S type) and the closely similar curves for the 8- and 12-cylinder models of l924-1927.

In suspension and braking systems there is little of interest to record, and it is true to say that little, if any, progress in these features was made during the two years under review. In frame design there is no doubt that the eight-cylinder Talbot was far in advance of its time, but it is something of a paradox that although the Delage, the most successful l½-litre car, had about the weakest frame ever put into any racing model (particularly as the designer made little use of the crankcase as a means of stiffening the front end) the road holding was quite good.

The most obvious development in chassis design during the two years 1926-7 was the off-setting of the transmission line. This, in turn, was directly inspired by the revision of regulations in 1925, whereby the car was manned by the driver alone. The result can be quickly gauged by an examination of the side elevations of the three typical Grand Prix cars which illustrate the relations of frame height, propeller shaft



As can be seen in this drawing of the experimental Fiat two-stroke engine (scale 1 : 4) the lower piston was used to uncover the exhaust ports and cold water was fed into the base of the cylinder. The geared-together crankshafts were placed slightly out of phase so as to permit early opening and closing of the exhaust ports in relation to the inlet ports.

and scuttle height. The net result was to reduce the frontal area of the 1927 Delage to about 9½ sq. ft. as compared to just under 11 sq. ft. for the Sunbeam of 1924, which may be taken as representative of the 2-litre Grand Prix cars. Lowering the c.g. improved cornering speeds, whilst the reduction in frontal area largely (but not entirely) compensated for the decrease in horse power which followed the cutting-down of engine capacity from 2.0 to 1.5 litres.

Reduction in power as between 1925 and 1927 was considerably less than the enforced diminution of capacity, so that by reason of reduced frontal area and weight, the performance factors did not fall in proportion to the loss of b.h.p.

In 1928 and 1929 the world attained a peak of inter-war prosperity which was not reflected in technical progress with racing cars.

Fiat who had entered in every Grand Prix race (with the exception of 1913), from 1906-25, had taken almost no part in the 1½-litre formula of 1926-27, although their racing department had been busy constructing twelve-cylinder cars with both two-stroke and four-stroke engines. In 1928 work on these was abandoned and the cars were put into storage. The Sunbeam-Talbot-Darracq coalition, the component parts of which had also engaged in racing from the first Grand Prix onwards, withdrew *in toto* in 1927 and sold their cars. Delage who had entered in every event since 1913 (except 1921-22) also sold their eight-cylinder, 1½-litre, cars to private owners in 1928, and had previously disposed of the 2-litres which had won the 1925 A.C.F. Grand Prix. Alfa Romeo had taken no part in the 1½-litre racing but from the beginning of 1928 the celebrated P2 models were entered in some races.

For most of 1928 works-sponsored entries were restricted solely to Bugatti, although he was joined by Maserati in 1929 and 1930. These three racing years may, therefore, be considered as a “carry forward ” from the previous 2-litre and 1½-litre formula, and it will perhaps put the period in proper technical perspective if we take the makes in alphabetical order and summarise their achievements.

Alfa Romeo

The P2 cars were factory owned and driven by Nuvolari, Brilli Peri, Varzi and Campari. In 1928 they won no races but Campari broke the lap record at Cremona. In 1929 Varzi won four races and Brilli Peri one, making a total of five wins. In 1930 Varzi was the only victorious driver with two wins, but Nuvolari broke the Montenero lap record.

Bugatti

Ettore Bugatti relied entirely upon the Type 35B and C cars, of 2.3 and 2 litres capacity respectively. With these he secured six wins in 1928 and made fastest laps in four races ; he had six wins and three fastest laps in 1929, and four wins with three fastest laps in 1930.

Maserati

The first product of the brothers Maserati to appear in the statistics of racing was a 1½-litre straight-eight with which A. Maserati won his class in the 1926 Targa Florio. Subsequently the same type of car won the flying kilometre contest at Bologna in 1926, averaging 104 m.p.h., driven by E. Maserati. Working on a modest scale the new company did not feel able to compete against large concerns in the international

1½-litre formula, but they continued to produce interesting designs, the capacity of the eight-cylinder car being raised to 2 litres. In 1929 they built a twin-engined version of this car which put up record laps on the Cremona Circuit and on the 2.8 miles used at Monza. This sixteen-cylinder model had further success in 1930, but it was in this year the marque really found itself with a 2½-litre car which was the only really successful new model to be produced in the period under review.

Talbot

The eight-cylinder racing cars built by the S.T.D. combine for the 1926-7 formula of 1½ litres were run as a privately owned team, some of the engines being bored out to give a capacity of *circa* 1,700 c.c; In 1928 the cars secured two victories and two fastest laps. In subsequent years they were not placed in major races.

One explanation of the comparatively luke-warm interest in Grand Prix racing during this period was the very great popularity of sports car events. The regulations for these competitions prescribed catalogue-type chassis (with certain stated deviations from standard) and four-seater bodies with full equipment, including electric lighting, starter and hoods were required.

Bugatti stood somewhat aloof from this type of racing but both Alfa Romeo and Maserati supported it, as did Mercedes-Benz and Bentley. Both Mercedes-Benz and Bentley also competed in Grand Prix racing, the former with a six-cylinder supercharged engine with 7.1 litres capacity developing up to 300 b.h.p., and the latter with a 4½-litre supercharged engine developing some 240 b.h.p. The former car was fast enough to win the German Grand Prix in 1928 and the latter make beat all but one of the normal Grand Prix types in the French Grand Prix of 1930 and is, for this reason given a place in the Examples, as No. 12. With the exception of the Mercedes and the sixteen-cylinder Maserati, the Bentley had the highest engine output of any car run in Grand Prix racing up to 1930, but although the h.p. per sq. ft. of the Bentley approximated to its rivals owing to the very high weight of the car it was sadly deficient in h.p. per laden ton.

The Mercedes-Benz was a smaller car with a larger and more highly powered engine, which made it an even more formidable challenger to the Grand Prix cars in this period. The popularity of sports car racing had, moreover, an indirect reaction in that the Grand Prix Maserati was designed so that it would also be eligible in the sports car class and provision for a dynamo and electric starter was therefore included in the original design. Production cost and maintenance problems also dictated the use of plain white-metal bearings, thus reversing the precedent established by Fiat in 1921-2, since which time all successful Grand Prix cars had used roller bearings throughout.

Apart from the question of eligibility in sports car races it is essential to remember that Bugatti and Maserati, i.e. the only constructors who entered cars with works drivers, were themselves largely dependent on orders placed by private owners, who were sensitive to both first cost and maintenance problems. In these conditions it was unreasonable to expect that performance factors would increase, and statistics of record attempts show that even in the last year it was made the Type 35B Bugatti was considerably slower than either the 1927 1½-litre Talbots or the 1925 2-litre Delage. The figures may be tabulated thus :

RECORD SPEEDS 1925-30

Car	*Standing Kilometre*	*Standing Mile*	*Average Kilo-metre to Mile*	*Maximum Mile or Kilometre*	*Date and A.I. No.*
1925 2.0 Delage . .	79.39 m.p.h.	93.68 m.p.h.	132 m.p.h.	134 m.p.h.	1 l/10/25 A.I.7
1927 1.5 Talbot	81.55 m.p.h.	92.33 m.p.h.	120 m.p.h.	129.75 m.p.h.	5/9/26 A.I.10
1930 2.3 Bugatti..	79.03 m.p.h.	90.77 m.p.h.	120.5 m.p.h.	125.21 m.p.h.	19/10/30 RAC4 & RAC17

But we have seen that the 1½-litre cars achieved circuit averages slightly higher than would be theoretically expected and this difference was continued, and even increased in the case of the Bugatti. It is thus self-evident that even if engine design was stagnant, chassis design was improving. One need only compare the general layout of the 1924 Sunbeam, 1927 Delage, and Type 35B Bugatti (Examples Nos. 9, 10 and 11 respectively) to perceive that this was indeed so. In particular, the frame of the Bugatti was properly designed as a beam with a centre section 6¾ in. deep, and also strongly stiffened torsionally by the four-point mounting of the sump which was rigidly attached to the side rails. The Bugatti, light alloy, brake drum cast in one with the wheels with an inserted liner was also a great step forward in heat dissipation and in stiffness of the drum, whilst in the general art of steering and suspension layout Ettore Bugatti knew no superior until the event of the independently sprung cars of 1934 or, one might say, of 1937.

In sum, from a technical viewpoint the lessons learnt in 1928-30 were particularly concerned with chassis design and this temporarily outran engine output which was limited by considerations of production cost and maintenance in the hands of amateur racing drivers.

CHAPTER FIFTEEN

The Second Decade

THE technical progress made in the first ten years of Grand Prix racing fell into three distinct phases, but in the second decade, by contrast, design flowed steadily along certain well-marked channels. These did not exactly align with the progress made in 1913 and 1914, for the break for the 1914-18 war (and the lessons learned during this period in aviation engines) resulted in a superficial discontinuity as between 1914 and 1920. This was most noticeable in the virtual disappearance of the four-cylinder engine from international racing and the emergence of the straight-eight as the dominant Grand Prix type.

In this respect it is illuminating to list various constructors of Formula cars together with the basic engine type, thus :

	FOUR CYLINDERS		
Aston Martin	1922	Vauxhall ..	1922
Ballot	1921-2	Mercedes	1924
	SIX CYLINDERS		
Fiat	1923	Sunbeam	1923-5
Voisin	1923	Benz	1923
	STRAIGHT EIGHTS		
Alfa Romeo	1924-30	Maserati	1929-30
Alvis	1927	Mercedes	1924-5
Ballot	1919-21	Miller	1924-5
Bugatti	1922-30	Rolland Pilain	1924
Delage	1926-7	Sunbeam-Talbot-Darracq	1921
Duesenberg	1920-21	Talbot	1926-7
Fiat	1923-5	Thomas	1927
	TWELVE CYLINDERS		
Delage	1923-5	Fiat	1927

As a consequence of multi-cylinders, piston area did not fall in the same proportion as the successive reductions in cylinder capacity which were enforced by international regulations, and here again, the facts stand out most vividly if presented in tabular form :

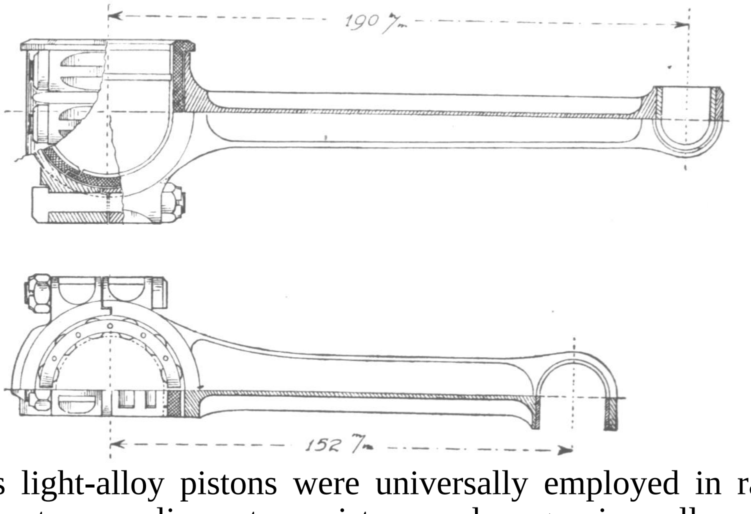
Years of Comparison	*Percentage Swept Volume*	*Percentage Piston Area*	*Percentage B.H.P.*
1914 (100) - 1921	66.6	98.5	93
1921 (100) - 1924	66.6	83	128
1924 (100) - 1927..	75	94	105
1921 (100) - 1927	50	73	135

It will be observed that in the face of a diminution of 27 per cent in piston area between 1921 and 1927, overall engine power rose by some 35 per cent and, keeping in mind the basic formula for power output discussed in Chapter 16, it follows of physical necessity that piston speed or mean effective pressure, or both, must also have risen.

During the first ten years of Grand Prix design piston speeds were approximately trebled and by 1914 engines were running reliably at 3,000 ft./min. Between 1920 and 1930 the increase was on a much smaller scale. A speed of 4,000 ft./min. was reached in exceptional cases, but it is doubtful if this could be sustained with reliability, and 3,500 ft./min. is a more reasonable figure to accept. In other words, the doctrine of the pioneer designers that engine output would be limited by piston speed was in principle correct, although the maximum figure has proved itself to be nearly four times greater than the thousand ft./min. upon which the arguments of 1902-6 were based. Whereas, however, on the 1914 four-cylinder engines the stroke was between 150 and 165 mm. (giving an approximate equality between the figure for piston and crank speed) by 1927 piston strokes had been halved and r.p.m. raised to *circa* 7,000 r.p.m. on the most highly developed engines.

It is not uninteresting that this change was accompanied by a positive and relative increase in the weight of the " reciprocating " parts, i.e. piston and connecting rod. As shown in Chapter 18 these parts weighed some 0.66 lb. per sq. inch of piston area on the first Grand Prix engines, but this figure was drastically reduced in the ensuing ten or so years by the employment of light-alloy pistons, by more careful stressing of the connecting rods, and the use of higher grade materials. On the 1908 basis, for example, the weight of an individual connecting rod and piston of the 1920 Ballot engine would have been about 3.1 lb. ; it was, in fact, only 1.03 lb.

From 1924 onwards increasing attention was given to the stiffness of the connecting rod and dissipation of heat from the piston, and for both reasons a greater mass of material was required. Hence, on the 1927 Delage the weight per sq. in. was 62 per cent greater than on the 1921 Ballot and only 46 per cent less than on the typical 1908 engine.



The 1927 Delage connecting rod (lower) shown to the same scale as the 3-litre Ballot rod.

From 1920 onwards light-alloy pistons were universally employed in racing cars, but experiments with cut-away slipper type pistons and magnesium alloys were not successful. Cast Y alloy pistons proved the most suitable, although in France it became common to use metal moulds and silicon alloys despite the small quantities

made. On high speed engines it was discovered that narrow (2 mm.) piston rings were most effective, and they were commonly placed fairly well down the piston to give protection from heat.

With the exception of the Maserati, introduced just before the end of the second decade, all the successful cars from 1922 onwards used roller bearings for the crankshaft and big ends, which tended in itself to increase the weight of the rod.

Light-alloy cages were used for the rollers, increasing attention was given to the stiffness of the bottom half of the big end, and it was normal to use a one-piece crankshaft with split races for both mains and big ends. This construction necessitated supremely accurate machining and assembly, but there was probably little difference in this respect from one-piece rods with a built-up shaft, as used by Vauxhall in their T.T. car and on the Type 35 Bugatti. With these two exceptions it was usual to split the crankcase on the centre line of the shaft, an arrangement giving good transverse stiffness.

All these roller bearing engines ran with extremely low oil pressures, oil normally being fed by jets into grooves cut round the crank webs and thence travelling under centrifugal force into the big ends. The large volume of oil thus freed in the crankcase made it imperative to use baffles at the base of the cylinder block in order to prevent excessive consumption and plug fouling. Dry sumps, scavenged by a separate pump, became almost universal.

Another feature common to all successful Grand Prix cars of the period (again with the exception of Maserati) was a detachable cylinder block with integral cylinder head. The French constructors, Delage and Bugatti, relied upon iron castings, Bugatti embracing four bores in one unit ; Delage six in one bank of the V12, 2-litre, and eight-in-one-piece with the later 1½-litre model. These blocks were extraordinarily fine examples of the foundrymen's art, and Delage in particular showed a very careful arrangement of water passages together with ample means for eliminating sand from the casting.

The Italian constructors followed the construction initiated by Mercedes in 1913 and used forged steel barrels with ports built up by welding. Sheet metal water jackets enclosed units of two or three bores. Sunbeam and Talbot, designed under the Italian influence, also followed this practice.

Both the Italian school of design and Delage in France used two valves per cylinder inclined at between 96 and 100 degrees, and in this respect there was, after 1922, a complete departure from the previously popular arrangement of having four valves per cylinder at an included angle of approximately 60 degrees.

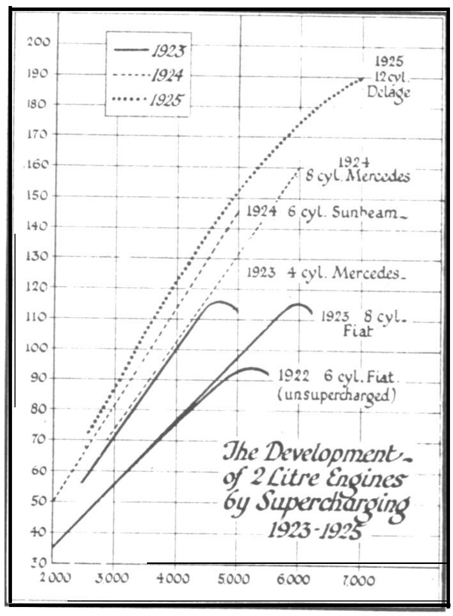
It is worth examining this change in some detail, as " breathing " is an all-important quality in the racing car engine, and, irrespective of manifold pressure, it is fundamentally determined by the flow values through the valve ports. From this point of view probably the most efficient four-valve engine ever built was the 1922 T.T. Vauxhall in which the inlet valve area equalled 43 per cent of the piston area, and the output per sq. in. of valve area amounted to 9.7 h.p.

The 1924 Sunbeam was an example of the wide angled, two-valve per cylinder, construction in which the inlet valve was made as large as possible, and the valve area on this car was 38 per cent of the piston area, a good deal better than on the 1927 Delage, for which the figure was only 30 per cent. Hence, at best, the two-valve engine

suffered from a reduced ratio of valve : piston area, but this was offset by careful port design, and less gas friction as a result of having only one guide and stem instead of two per cylinder. In consequence, at a common piston speed of 4,000 ft./min., the output per sq. in. of valve area on the 1927 Delage engine was 90 per cent greater on the 1922 Vauxhall, although the manifold pressure had only increased by 50 per cent, from 1.0 to 1.5 Ata.

Increased valve overlap and the extension of the total period of inlet valve opening also contributed to the increased effectiveness of a given valve area.

On the 1922 six-cylinder Fiat the inlet valve opened at top-dead-centre and closed 50 degrees after bottom-dead-centre, so that it had a total opening of 230 degrees. On the 1927 Delage the inlet valve opened 18 degrees before top-dead-centre and closed



50 degrees after, a total opening of 248 degrees. On the 1924 Sunbeam the inlet valve opened 10 degrees before top-dead-centre and closed 62 degrees after bottom-dead-centre with a total dwell of 252 degrees.

Perhaps even more important from the viewpoint of sustained power at high r.p.m. was the increase in valve overlap on each side of top-dead-centre, for this powerfully influenced scavenging and the total weight of fresh charge passed into the cylinder.

On the 1922 Fiat the exhaust valve opened 50 degrees before bottom-centre and closed 10 degrees after top, the overlap on this engine being, therefore, only 10 degrees.

On the 1924 Sunbeam the same opening point was used, but five degrees were added to the exhaust closing point, so in conjunction with the earlier opening of the inlet valve the overlap was 25 degrees. On the 1927 Delage the exhaust opened 58 degrees before bottom-dead-centre, and closed 25 degrees late, the overlap (vis-à-vis the inlet valve) being 43 degrees.

Bugatti, perhaps more than any other constructor, took great care to fully evacuate the exhaust gases. He made the area of the single exhaust valve 20 per cent greater than that of the dual inlet valves and used two four-branch pipes from the

exhaust manifold, each of which was brought to a centre-point in such a way as to give extractor effect as between the discharge of one cylinder and another. Unfortunately, by using vertical valves and somewhat crude inlet manifolds, Bugatti lost on one side of his engine much of what was undoubtedly gained on the other, and it is, therefore, difficult to make a direct comparison between his design and the more usual inclined valve type.

The replacement of natural by forced induction in 1923 was the biggest single step towards a divorce between engine size (irrespective of standards of measurement) and developed h.p. When Mercedes and Fiat had shown that supercharging was a practical proposition there were many who held that it should be excluded because it violated limited capacity regulations, as undoubtedly, in strict logic, it did. Others claimed that the designer should be free to explore every method of raising power, and that if added charge weight were illegal, so also were added r.p.m., for both in effect were merely a means of increasing the air consumption per minute.

It is a matter of record that after 1914 there was no interference in the development of the supercharger, nor even a handicap imposed upon it, and the advantages of using increased manifold pressure proved to be so great that one may reasonably ask why blowers were not used experimentally before 1923.

It is problematical whether the earlier engines with cast-iron heads and ferrous pistons would have been capable of withstanding the additional thermal loading imposed by supercharging, and significant that the first successful, blown, road racing cars all had welded steel cylinder construction. A comparison of the cross-sections reproduced of 1913 Peugeot, 1914 Vauxhall and 1922 Aston Martin cylinder heads with the 1926-7 Talbot and Delage designs shows the very big improvement embodied in the latter.

The designers of the '20's did not resort to such expedients as directed high velocity water and internal cooling by excessively rich alcohol mixture, but they soon found that added engine power could be obtained by using alcohol fuels to reduce manifold temperature. An example showing a gain of 5 per cent has been quoted on an earlier page, and this in turn followed upon the discovery that petrol-benzol mixture induced through the blower had a similar effect and by itself would produce a gain in power of some 20 per cent, as mentioned in a previous chapter. Thus test bench results indicated that a supercharged engine, aspirating alcohol fuel through the blower, would develop 26 per cent more power than the same engine, mechanically unchanged, but supplied with pressure air to a carburetter fed with petrol.

Early diverse opinion about types of blowers soon gave place to unanimous acceptance of the Roots type with two or three paddles. Centrifugal blowers proved admirably suited for high speed tracks, e.g. Indianapolis in the U.S.A., and also on road courses suitable for very high average speeds, such as Monza (as witness the 1925 performance of the Duesenberg), but on real road circuits, the pronounced drop of the b.m.e.p. curve characteristic on centrifugal supercharged engines made the type wholly unacceptable.

The positive displacement blower with internal eccentric mounted drum and sliding vanes, although an efficient air compressor, proved mechanically incapable of surviving the severe conditions of road racing and after early experiments by both Mercedes and Fiat, this type was abandoned. The simplicity and robust construction of the Roots blower (which needed no positive lubrication in the pumping chamber

apart from 1 or 2 per cent of oil mixed with the fuel), its light weight and ability to run at engine speed, put it in an unchallengeable position, despite admitted inefficiency as an air pump at over 10 lb. contra pressure. This was masked by relatively low supercharge pressures, for until 1930 no designer had used more than one atmosphere boost.

We can summarise gains in specific engine output of 1920-30 as follows :

B.H.P. per Litre	*B.H.P. per sq. in. of piston area*	*B.M.E.P.*	*Piston Speed*	*R.P.M.*	*Manifold Pressure*
I.0 : 3.15	1.0 : 1.80	1.0 : 1.59	I.0 : 1.14	10 : 1.70	1.0 : 1.90

As a direct consequence of aspirating through the blower, the practice of using more than one carburetter fell into desuetude. A single instrument with barrel-type throttle became normal with Italians using principally Memini and other countries' Solex instruments. Fuel was supplied by air pressure.

Experimental use of battery and coil ignition in the period 1920-2 gave way to the almost universal employment of Bosch magnetos supplying current to KLG 18 millimetre sparking plugs with mica insulation.

Chief progress in the transmission of power from the engine to the rear wheels lay in the unit construction of engine and gearbox, but here again Bugatti held to the heterodox and continued to mount the gearbox separately in the centre of the frame.

Duesenberg demonstrated in 1921 that a three-speed gear was no bar to success in road racing, and Louis Coatalen, always quick to observe new trends in design, saw to it that a similar box was always used on the Henri-designed 2-litre Sunbeams of 1922. In the smaller engined car this experiment was not a success, and Sunbeam reverted to four-speed gearboxes from 1924 onwards. The only exception to this number of gears amongst European cars were the twelve- and eight-cylinder Delages, which used a geared-up fifth speed ; a practice initiated by Delage in 1913 which was especially appropriate to the very high speed, supercharged engines produced between 1925 and 1927, for it was possible to take full advantage of, so to speak, an emergency power output at 8,000 r.p.m. on direct drive and yet to relieve the engine from unnecessary stresses by reducing speed to some 6,700 r.p.m. on long straights. It will be obvious that such transmission introduces complications when evaluating performance factors, and for this reason the tabular data for the 1927 Delage has double entries.

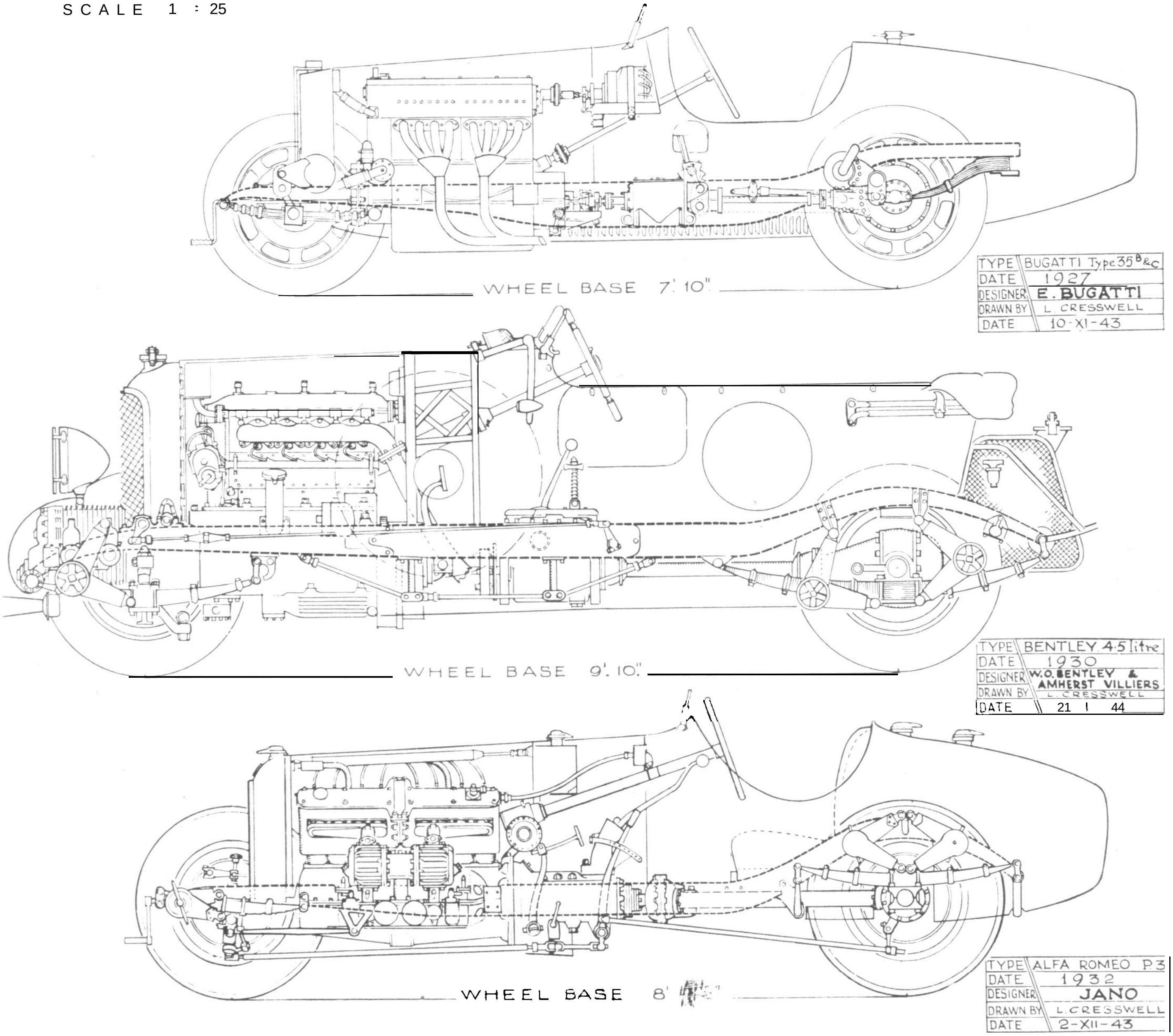
No clear-cut superiority can be awarded to the rival arrangements of torque tube and Hotchkiss drive. The Italian designers favoured the former ; the French, the latter, with Bugatti compromising by using an open propeller shaft, two universal joints, plus torque and radius arms..

In the physical construction of the rear axle it became the general practice to employ a steel or light-alloy housing, split vertically, for the bevel gears and differential pinions; and to bolt thereon steel tubes enclosing the half shafts. Semi-floating axle shafts were used, and although these had the disability that breakage of a shaft meant the loss of complete hub and wheel, there were gains in respect of lightness and mechanical simplicity.

Weight of axles and brake gear both fore and aft was, at this stage of racing car design, proving a very serious problem. In particular, adding cast-iron brake drums

of 14 in. diameter to the front axle raised the unsprung weight at a time when total weight was falling both by reason of chassis design and also by the elimination of the weight of the mechanic from 1924 onwards. All-up starting line weight was reduced from 23 cwt. to 18 cwt. between 1921 and 1930, and assuming that the total mass of

SCALE 1 : 25



the unsprung parts remained 5 cwt., the ratio of the sprung : unsprung masses fell from 3.6 : 1 to 2.6 : 1 ; that is by nearly 30 per cent. Simultaneously, maximum road speed rose by about 16 per cent, giving rise to an increase in the inertia loading due to impacts from an uneven road surface of some 35 per cent.

Road holding and control were thus attacked by two enemies at once, and designers resorted to the expedient of reducing spring rates and using such a high degree of friction damping that wheel movement was almost imperceptible except under very heavy impacts,

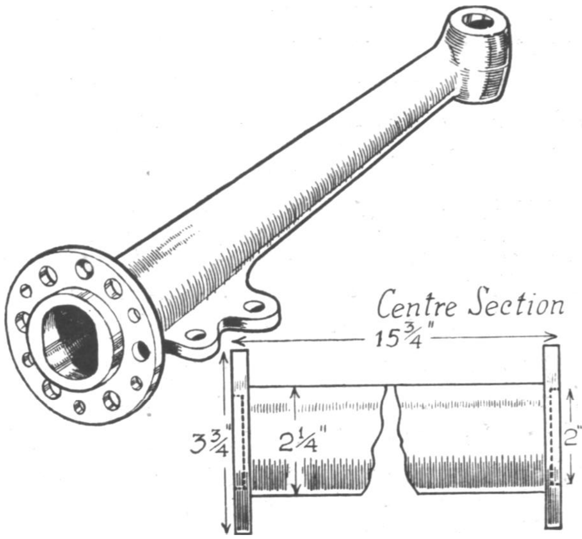
With a suitably stiff chassis, as on the Bugatti, this gave tolerable road holding at the expense of a very hard ride which inflicted considerable physical punishment on the driver. Contrary, therefore, to popular opinion the light 2-litre and 1½-litre cars of 1925-30 were more difficult, and tiring, to drive than the exceedingly large cars with very light axles which were constructed in the first decade of motor racing.

With the exception of Bugatti, all constructors used Hartford shock absorbers of the scissors pattern, and in many cases two pairs were used on each side of the front axle. Additionally the springs were frequently bound with cord further to increase the friction damping available.

Steering gears showed little change in the period under review, worm and wheel mechanism giving approximately 1¾ turns of the steering wheel over full lock of the road wheels being employed almost universally.

As regards the brakes themselves it may be said that the '20's were the heyday of the mechanical braking system with full compensation and servo operation.

The drawing shows the unusual front axle of the Delage which was made up in three sections and bolted together.



Although the application of equal unit pressures between lining and drum on all four wheels does not necessarily produce even braking effort, designers took it as a *sine qua non* that such equal pressures must be sought. Bugatti achieved them with great simplicity by employing chains running over sprockets to give a fore and aft balance and a miniature differential gear to compensate as between one side of the car and the other.

Other engineers resorted to considerable mechanical complications and accepted the use of cables running over small diameter pulleys which led to low mechanical efficiency as between the pedal and the brake cams. Additionally, owing to the high rate of wear on the somewhat primitive brake linings used at this time it was imperative to avoid a high mechanical advantage. In these circumstances the provision of servo aid was a matter not of choice but of necessity.

It became usual to connect the brake pedal to expanding shoes in a drum driven off the back of the gearbox, the reaction of this drum being used to apply the main braking system, but contemporary reports of motor racing, nevertheless, make constant references to deterioration of braking power as races went on, and there is no doubt

that at this period brakes were a limiting factor in circuit speeds. Here again Bugatti achieved substantial advantage over his rivals by using a single light-alloy casting for both wheel and drum. This very much improved heat dissipation from the drum and conferred great stiffness. Additionally, when the wheels were changed the shoes were exposed, and it was possible to put in newly lined shoes during the course of a race. This not only restored the braking power of the car ; it also encouraged drivers to make the best possible use of the brake mechanism during the early stages of the event and permitted record breaking laps to be put up without fear of subsequent penalty,

Race averages also benefited from improvements in tyre construction and the beaded edge type was replaced by straight-sided tyres. There was also a trend towards smaller rims and overall diameters, the latter falling from 32 in. to 30 in.

The success of the 1922 Fiat served to set a style in body design which persisted for more than ten years and which entirely superseded the two previously popular shapes. Up to 1913 the typical racing car body had consisted of two seats, behind which were placed a cylindrical fuel tank and one or two spare wheels mounted athwart the car. The 1914 Peugeot embodied a long cigar-shaped tail which was copied by all the entrants in the 1921 Grand Prix and by almost all in the 1922 Grand Prix. In the latter year, however, Fiat ran with a triangular, flat-sided, tail, and, with the exception of unsuccessful streamlined deviations by Benz, Bugatti and Voisin in 1923, the Fiat *motif* was adhered to throughout the whole of the second decade.

In 1925 and 1926 two-seater bodies were required, but the driver only formed the crew, and what constituted a mechanic's seat could be somewhat liberally interpreted, including a metal cowl over half the cockpit. In 1927, and onwards, no second seat was called for, and Talbot and Delage cars, specifically designed for 1926 and '27 racing, had offset propeller shafts which permitted a marked reduction in the height of the driving seat. As shown in an illustration, this led directly to a reduction in frontal area of about 15 per cent. It should, however, be put on record that this method of reducing frontal area was unique, for the precedent they established was not followed either in the closing years of the second decade or (with one exception in 1939) thereafter.

We have seen that potential lap speed increased by about 12 per cent in the six Grand Prix races held between 1906 and 1914, an average of 2 per cent per annum. This rate of increase was almost exactly sustained during the second decade during which the average speed index *vis-à-vis* the 1906 Grand Prix Renault rose to 132. On a direct derivation of the formula which suggests that average speed index varies as the square root of maximum speed, one would thus expect that cars of 1930 would have a maxima of some 147 m.p.h., taking into account the influence of front wheel brakes. The writer has suggested that these by themselves improved circuit speeds by some 5 per cent ; but allowing for this the theoretical maximum speed of the 1930 car overstates the speed actually realised by some 10-12 m.p.h. We must, therefore, infer that apart from the use of front brakes, improvements in chassis design made during the second decade of motor racing, were the equivalent of an added 10 m.p.h. in maximum and thus worth a gain of 25 per cent in engine power.

This gap, between the average speed to be theoretically expected and that attained in practice, widened in the first two or three years of the third decade of racing, but the implications of this fact are more properly left to the ensuing chapter.

STATISTICS FOR RACING CARS, 1920-1930

	1920 *Ballot*	1921 *Duesenberg*	1922 *Vauxhall*	1922 *Fiat*	1924 *Sunbeam*	1924 *Fiat*	1925 *Delage*	1926 *Talbot*	1927 *Fiat*	1927 *Delage*	1929 *Bugatti*	1930 *Bentley*
Cylinders	8	8	4	6	6	8	12	8	12	8	8	4
Bore M/M	65	63.5	85	65	67	60	51.3	56	50	55.8	60	100
Stroke M/M	112	117	132	100	94	87.5	80	75.5	63	76	100	140
S/B Ratio	1.73	1.84	1.55	1.54	1.4	1.45	1.55	1.35	1.26	1.36	1.67	1.4
Engine capacity CM^3	2960	2950	2996	1991	1988	1980	1984	1485	1434	1488	2261	4486
B.H.P.	107	115	129	92	138	146	190	145	160	170 (142)	135	240
R.P.M.	3800	4250	4500	5200	5500	5500	7000	6500	8000	8000 (6500)	5300	4200
B.H.P. per litre	35.7	38.5	43	46	69.5	73	95	97	107.5	113 (94)	58.7	53.5
B.M.E.P. lb./in.^{2}	122	113	125	115	170	169	175	194	175	177 (190)	134	165
Piston Speed ft./min.	2800	3270	3900	3420	3400	3150	3700	3230	3320	4000	3500	3860
Piston area sq. in.	41	39.3	35.2	30.8	32.9	35.1	38.7	31	36.6	***30.4***	***35***	***48.5***
H.P. per sq. in. piston area	2.64	2.93	3.66	3	4.2	4.66	4.9	4.68	4.5	5.6 (4.65)	3.85	4.95
Piston area sq. in. litre	13.4	13.3	11.8	15.4	16.5	17.5	19.3	20.8	24.3	20.4	15.2	10.8
Inlet valve area sq. in.	17.5	12	13.3	11.2	12.5	13.4	12		13.2	9.3	10.10	13.6
H.P./sq. in. inlet valve area	6.1	9.6	9.7	8.1	11	10.9	15.8	—	10.1	18.3 (15.2)	13.4	17.7
Rod and piston weight lb./cyl.	1.03	1.15	1.7	—	2.15	—	—	—	—	1.38		
Weight of rod and pistons per sq. in.	0.22	0.232	0.195	–	0.392	—			—	0.356	—	—
Induction system	Ata.	Ata.	Ata.	Ata.	1.47 Ata	1.6 Ata	1.5 Ata	1.95 Ata	1.9 Ata.	1.5 Ata	1.66 Ata	1.82 Ata.
Frontal area sq. ft.	12	*12*	14	12.2	10.8	*11.0*	11.0	*9.5*	*9.5*	9.5	10.8	17
H.P. per sq. ft.	9.3	*9.75*	9.3	7.6	12.7	*13.25*	17.3	*15.2*	*16.8*	18 (14.9)	12.6	14.2
Weight cwt. (1 cwt.= 112 lb.)	18	*18*	22.5	13	15.7	*14.0*	*16.0*	*14.5*	*14.0*	15.8	15.1	38
Weight cwt. with crew and fuel	23	*23*	27	18	20.7	*19.0*	*21.0*	*18.0*	*19.0*	19.3	18.5	41.5
Engine litres per laden ton (2,240 lb.)	2.6	*2.6*	2.22	2.22	1.87	*2.1*	*1.92*	*1.66*	*1.58*	1.56	2.5	2.17
Engine B.H.P. per laden ton (2,240lb.)	93	*100*	***95.5***	103	128	*154*	*182*	*163*	*168*	177 (142)	146	116
Max. road speed : m.p.h.	112	114	112	106	125	*136*	134	130	*135*	128	125	130

Notes.-The 1927 Delage engine output figures are " corrected " to 142 b.h.p. at 6,500 r.p.m. for continuous operation.
The 1922 Fiat figures are as obtained at Strasbourg ; as at Monza all the output figures should be raised by 16 per cent.
Figures in italics are estimates or derivations therefrom or makers' claims.

CHAPTER SIXTEEN

End of the Beginning

BY 1930 three facts were clear to all engineers engaged in the construction of racing cars. These were :

(a) The 2½-litre Maserati was the fastest car yet built on a road circuit.

(b) The margin of Maserati supremacy was such that it could not be successfully challenged by minor modifications to existing designs.

(c) Improvements in roadworthiness appeared to offer an opportunity to increase engine power above existing figures, which had been more or less static for the past five years.

The International formula for 1931 proved in the end to be simply an obligation to run races for ten hours. Designers were free to fit any size of engine, and 1931 was thus the fourth successive year in which no limit had been placed on swept volume.

In 1929 the brothers Maserati had built a car in which they installed two 2-litre eight-cylinder engines coupled together. They ran it first in the 1929 Cremona Prize and although failing to win it lapped at the somewhat startling speed of 124.4 m.p.h. and was timed over 10 kilometres at the astonishing velocity of 152.9 m.p.h. In 1930 the car won the Tripoli Grand Prix which, it should be noted, was not yet run over the later, and better known, Mellaha Circuit, and although later in the year at Monza the car was beaten by two 2½-litre Maseratis it had demonstrated the possibilities of cars powered with engines of 1914 capacity with 1924 power per litre.

In 1931 both Alfa Romeo and Bugatti decided to build along these lines. The former company followed Maserati practice most directly by installing two six-cylinder supercharged 1,750 c.c. engines into one frame, but as mentioned in Volume I each engine retained its own transmission system complete from clutch to bevel gears. Largely in consequence of this, the all-up weight was nearly half as much again as corresponding single-engine cars, so that although there was some 220 b.h.p. under the bonnet the car was not particularly successful.

This model ran twice at Monza, firstly in the European Grand Prix from which it retired at the end of two hours when running in third position, and three months later in the Monza Grand Prix in which it made fastest lap of the day but never reached higher than third position. The lap speed was some 1½ m.p.h. faster than that put up by the 2½-litre Maserati on the same circuit in the previous year.

Bugatti, also, introduced his version of the big capacity car in the 1931 Monza Grand Prix and it took the form of a large straight eight, with bore and stroke 86 x 107 mm. and 90 degree valves operated by twin overhead camshafts. With characteristic ingenuity Bugatti contrived to fit this engine into a chassis (Type 54) virtually identical with the Type 35, and for some reason he decided to combine a three-speed gearbox with the rear axle. This had a 3.46 : 1 final ratio and 32 x 6 tyres, making the car run at 26½ m.p.h. at 1,000 r.p.m.

Exact figures are lacking, but it is improbable that the engine could exceed 5,250 r.p.m. with a corresponding maximum road speed of just under 140 m.p.h. With perhaps twice as much power as the previous Type 35 the acceleration of the car was outstanding but the three-speed gearbox was a handicap and the additional engine weight undoubtedly sullied the superlative road holding characteristics which had served Bugatti so well during the previous five years.

Monza was the only race in 1931 in which the Bugatti appeared (and any chance it had was ruined by tyre failures), but the sixteen-cylinder Maserati ran twice, winning the Rome Grand Prix for the second year in succession. At Monza it was slower than the smaller cars from the same factory.

In the ensuing year of 1932 Alfa Romeo abandoned development work on their double six, but both Bugatti and Maserati continued with their big cars. The latter made fastest lap on the A.V.U.S. track at the beginning of the year and poor pit work alone stopped it from winning the Italian Grand Prix at Monza in June, 1932. Denied first place by a stop of over three minutes Fagioli nevertheless put in a lap at 112.22 m.p.h., that is to say over 7 m.p.h. higher than the previous record speed.

By comparison the Type 54 Bugattis were very disappointing. They won no race, they broke no lap records, and although fast in the early stages of both the Italian and French Grands Prix they appeared to tire their drivers and be ineffective racing machines.

In sum, attempts to combine larger than 3-litre engines developing 220 b.h.p. or more in a chassis with conventional axles were a failure. Bugatti persevered with his Type 54 until 1933, and won the A.V.U.S. race in that year together with a fast lap at Monza, but the real racing successes in the years 1931, ‘32, and ‘33 were scored by cars with 2-3 litres capacity and 150-200 b.h.p. which were direct developments from the immediately preceding eight-cylinder models.

Maserati, of the three leading constructors of Grand Prix cars in 1931, made the least change, contenting themselves with increasing the capacity of their straight-eight engine from 2½ to 2.8 litres by enlarging the cylinder diameter.

Bugatti also changed but little externally so that the difference between the 1931-2 Type 51, 2.3 litre car and the preceding Type 35 models was impossible to detect. But although the chassis remained virtually identical the engine received a new cylinder block, the integral head of which carried two valves inclined at 90 degrees operated by two overhead camshafts. There is good reason for believing that the port shape and general layout of the valve gear was strongly influenced by the American Miller eight-cylinder engines, but, be this as it may, the engine had a typical Bugatti appearance with square section cam boxes.

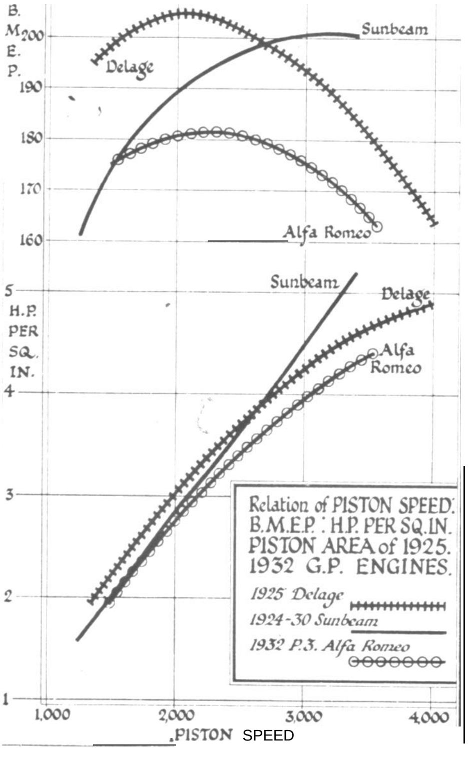
The supercharger remained on the side of the crankcase, as on the Type 35, but the inlet manifold was changed giving a more direct passage from the blower to the ports. The improved breathing afforded by the new head raised the power output of this engine by about 25 per cent and this in turn led to a useful increase in maximum speed and acceleration.

These improvements coupled with fine road holding and great reliability gave Bugatti a highly successful year.

In contrast to Maserati and Bugatti, Alfa Romeo produced an entirely new car in parallel with their twin six. This had a 2.3-litre eight-cylinder engine which,

as mentioned in Volume I, had many features in common with their existing six-cylinder 1,750 c.c. sports car engine and was itself used as the basis of a catalogue sports model in later years. It may be doubted whether this engine developed more power than the earlier roller bearing, steel cylindered 2-litre P2, but it almost certainly had better low end performance and was installed in a far more robust chassis with large diameter brakes. Hence, whereas in 1930 the inability of the six-year-old P2 to keep pace with the 2½-litre Maserati had been abundantly proved, in 1931 the 2.3-litre Monza was a definite competitor with the developed 2.8-litre Maserati.

In all three cars the driver sat on the right-hand side of the frame in a body of two-seater shape with one side cowled over. The space which would normally be occupied by a mechanic was often utilised for spare fuel tanks or oil tanks.



These selected output curves show that on absolute bases (H.P./sq. in. and B.M.E.P. cf. piston speed) engine design was static from 1924 to 1932.

The P3 Monoposto Alfa Romeo was a single engined model directly developed from the twin engine car built in the previous year. As on the Twin Six the driver was positioned centrally and the single engine and gearbox were joined to a double propeller shaft system, the elements of which are illustrated. The engine was basically similar to the Monza, the bore being unaltered but the crank radius being increased from 44 mm. to 50 mm. so that the capacity was raised from 2.3 litres to 2.65 litres. Additionally, the inlet system was removed from the right-hand side of the engine and mounted on the left-hand side and two blowers were used each feeding one bank of cylinders. As shown in the Example No. 13, Volume I, the basic performance factors for this car were considerably higher than anything hitherto known ; the h.p. per laden ton was 18 per cent more than on the Type 51 Bugatti and the h.p. per sq. ft. of frontal area 28 per cent greater.

Engine performance was not in itself outstanding whether it be judged on the basis of h.p. per litre, square inch of piston area, or b.m.e.p. On a power per litre basis the engine shows a marked regression as compared with the roller bearing,

steel cylinder power units of the 1923-7 era, but on the absolute basis of comparison one sees simply that performances had remained static for nigh on ten years. We can, for instance, make an interesting study of the 1926 Talbot, eight-cylinder, l½-litre car, and the Alfa Romeo engine, thus :

BASIC PERFORMANCE FACTORS OF 1926 I½-LITRE TALBOT AND 1932 P3 ALFA ROMEO

	1926 Talbot	*1932 Alfa Romeo P3*
R.P.M.	6,500	5,400
Piston Speed FT./MIN.	3,230	3,550
H.P. sq. ins. Piston Area	4.68	4.65
B.M.E.P.	194	172
Manifold Pressure Ata	1.95	1.6
H.P./Litre	96.5	71.5

The Alfa Romeo gave 2 per cent less power per sq. in. of piston area running at a 10 per cent higher piston speed with 15 per cent less boost, so clearly the degree of skill put into the design was the same in both cases. But the later engine was deliberately conceived as a compromise between size and weight, required power and ease of construction and maintenance, whereas, if the layout had been projected along the genealogical lines of the 2 and l½-litre limit engines, we should have seen either a 200 h.p. 2-litre, eight-cylinder engine running at 6,500 r.p.m., or a 2.65litre, twelve-cylinder developing some 270 b.h.p.

The construction of such engines was, indeed, advocated by a number of persons in the Alfa Romeo Racing Department but considerations of cost and time determined Jano to rely on the concept that racing car engines must bear a close resemblance to the production power units which were being built in quantities in the works at the same time.

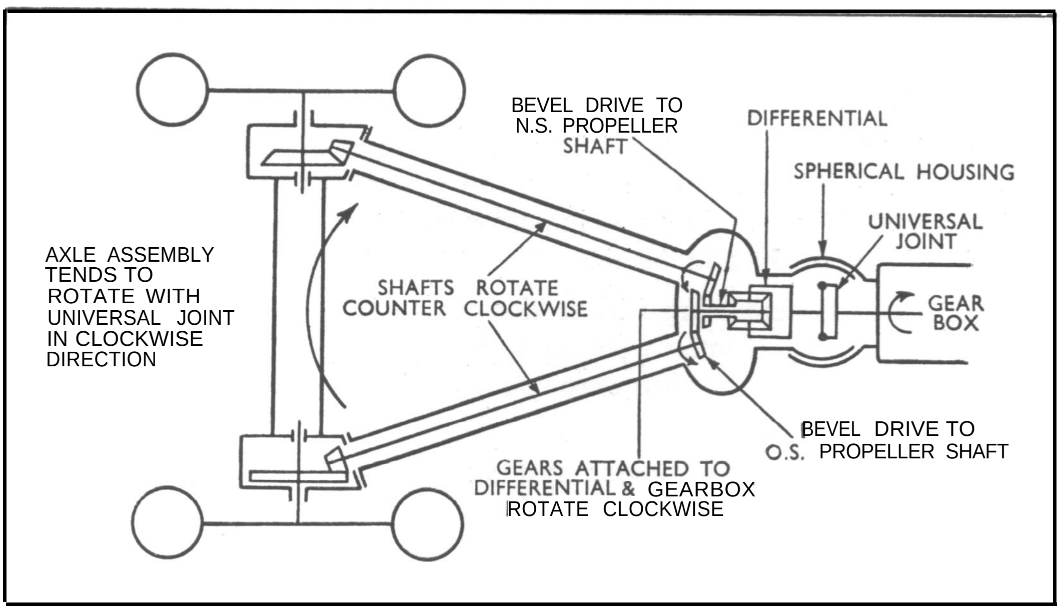


Diagram of the final drive of the P3 Alfa Romeo

An examination of the P3 chassis design shows that the designer had introduced many details promoting high average speeds. The front axle was located by a radius rod to prevent negative castor angle under heavy braking, and the brakes themselves were of exceptional diameter, giving 380 sq. in. of brake drum area per ton as compared with 294 sq. in. on the Bugatti and 270 sq. in. on the 1927 Delage. A four-point engine mounting promoted stiffness of the frame at the front end and the mounting of the rear springs was, as shown in the side elevation of the car, so disposed as to give an exceptionally high roll centre with improved stability.

The unusual construction of the rear axle offered certain benefits which may have been noticed on the road at the time but concerning which theoretical work has only been started some 15 years later. Recent research on cars fitted with conventional axles shows that if rear wheels are rotated on large diameter rollers with cams attached there is a marked pre-disposition to " hop " with each wheel hub traversing an ellipse. If the weight represented by the central bevel housing be redistributed close to the hubs this " hopping " tendency is eliminated and this is, of course, precisely what was done in the design of the P3 Alfa Romeo.

For differing reasons one would, therefore, expect both the front and rear wheel adhesion of the P3 to be a marked improvement upon previous designs and it is in these qualities that the merit of the car primarily resides.

But both the 1931 2½-litre Maserati and, even more, the 1933 bored out 2.9-litre edition of the same year also had a higher lap speed index than would be expected and the latter was nearly as fast as the P3 Alfa Romeo-when driven by Nuvolari it was faster.

In 1933, Maserati followed the example set by the P3 Alfa Romeo and brought out a car with central driving position and, *inter alia,* hydraulic brakes. The change in body form certainly reduced frontal area and as compared with the 2.65-litre P3 engine the Maserati probably developed an additional 15 or 20 b.h.p.

This notwithstanding, no more than 194 b.h.p. per sq. ft. can be ascribed to the Maserati and the coincident theoretical maximum speed of 145 m.p.h. gives an average index on paper of not more than 132, six per cent less than it achieved.

There was no correspondingly noticeable change in basic design and we must, therefore, ascribe this phenomenon to a general improvement in chassis layout coupled with undoubted strides made in the design of two important components viz. : tyres and brake linings. Up to 1925 tyre sections and pressures remained changed but little. Overall diameters fell from 35 in. to 30 in., cross sections rose from 4½ in. to 5½ in., with pressures lying between 50 and 60 lb.

In 1930, Bugatti were using 5 in. section tyres with an overall diameter of 29 in., and two years later Alfa Romeo were equipped with 5½ in. section tyres with 28 in. diameter. These increases in section were coupled with decreases in pressure, the figure dropping to 35/40 lb.

Due to the stiffness of springing systems the tyre played an important part in absorbing road shocks and there is no question that these developments markedly improved adhesion on corners and reduced wheel spin when accelerating from low speeds. Hence tyres by themselves were definite contributions to higher averages on the same h.p.

Developments in brake linings were probably even more important and as practically all the road racing cars of this period used linings made by Ferodo Ltd., it is of value to have a contribution from a member of this company. Mr. W. E. Shilton writes :

> The years 1928 to 1932 certainly did represent a time interval in which Ferodo Ltd. pioneered a very definite development in automotive brake linings, which had its effect on the performance of racing car brakes. Up to 1929-30 the brake lining with the greatest resistance to the severe conditions obtaining in racing was Ferodo Bonded Asbestos in its die-pressed or maximum density form. This material had a satisfactory resistance to wear at drum temperatures of 190-210 degrees C., but at higher values exhibited an appreciable fade. Judged by modern standards its average coefficient of friction was somewhat low at around 0.33. However, in 1929-30, we had developed Ferodo M.R., a non-metallic asbestos-base friction lining, with a practically infusible impregnant, to the stage at which it could be placed on the market, and it immediately proved to have about half the rate of wear of any previous high duty friction lining, allied to an increase in coefficient under normal conditions to a value between 0.38 and 0.4. At the same time elimination of the brass wire, which was previously an almost universal feature of asbestos base friction fabrics, showed that this feature largely eliminated drum scoring on the then widely used steel brake drums.
>
> I would say that the introduction of the present-day comparatively high friction coefficient lining, in the shape of Ferodo M.R., had quite a definite influence on the average speed at which a given circuit could be completed. At the same time it must be admitted that much more attention was being focused on road holding, steering, and last, but not least, on the mechanical detail work in the current brake hook-ups, improving the efficiency of the latter, and allowing a very much greater proportion of the driver's pedal effort to be available at the brake lining surface.

In the above note Mr. Shilton does not refer directly to the employment of hydraulic brakes by Maserati, but there is little doubt that the use of this system and the consequent total abolition of the friction wasting compensating devices improved the overall efficiency very considerably. Hydraulic brakes had, of course, been used in 1921 by Duesenberg in the Le Mans and in 1922 by Bugatti in the Strasbourg Grand Prix. There seems no explanation other than innate conservatism why fluid braking systems fell into disuse during the ten subsequent years. As we shall see, once they had been revived they were used in practically all subsequent designs.

When the proposition relating maximum to average speeds was laid down it was hedged with the condition that it was true for cars of similar size, weight, and standards of roadworthiness. Obviously the detail developments made in the five years after 1927 improved the standard of roadworthiness and in order to bring the factors back into line it has been proved that a correction of 6 per cent on average index is required to complement the 5 per cent addition which was brought into account for the benefits of front brakes. This combined bonus of 11 per cent means that a P3 Alfa Romeo with the same standards of braking and roadworthiness as the 1906 Renault would have needed a 600 b.h.p. engine, giving a maximum speed of 210 m.p.h., in order to reach the same lap speeds as were obtained in 1932 with a maximum speed of 140 m.p.h. and an engine developing less than 200 b.h.p.

This is an achievement for which the automobile engineers who contributed to it may be justly proud. The racing cars designed in 1933 represent the finest flowers of the orthodox design restricting itself to rigid axles, leaf springs with conventional engine position and transmission systems. How their blossoms wilted, and within two years were shrivelled, under the hot sun of heterodoxy and teutonic technical development, will be the subject of the next chapter.

CHAPTER SEVENTEEN

Rapid Advance

DURING the six years extending from 1928 to 1933 racing cars had in effect been built under *formule libre,* but, nevertheless, all the road racing wins and, except 1929 Cremona, record laps were secured by cars using engines of less than 3-litres capacity developing under 200 b.h.p.

As we have seen in the previous chapter attempts were made to use larger engines giving greater power but these experiments failed as the greater weight and poorer handling qualities of such cars more than offset gains in paper performance.

It cannot be doubted that when the Alfa Romeo and Maserati cars for the 1934 season were being considered these lessons were borne in mind, and it is interesting that neither of these companies had to make any marked change in design in order to bring their cars within the weight limit of 750 kg. Both had to increase the cross-section of the body in order to comply with a minimum width of 34½ ins. and Maserati simultaneously increased the width between the side rails of the frame. Alfa Romeo, also, slightly enlarged the wheelbase and track of their existing P3 straight-eight car and made a more important change by raising the cylinder diameter by 3 mm., thus bringing the capacity up to 2.95 litres. For 1934 the car was called the P3 Type B.

Both the Italian engines probably developed between 200 and 215 b.h.p. at the beginning of the 1934 season and both represented tried and trusted types which could be relied upon to combine high average speeds with complete reliability.

In France, Ettore Bugatti had spent the whole of 1933 struggling to make his new design of racing car *au point,* but he did not succeed in bringing it on-to the starting line until the Spanish Grand Prix at the end of September and, with 2.8-litre engine capacity, it was clearly outclassed by both its immediate rivals. This car, the Type 59, was in no way a direct projection of previous Bugatti practice. The quarter-elliptic rear springs and the semi-elliptic front springs passing through the tubular axle were, it is true, retained, but the straight-eight engine had plain bearings throughout with the timing gears at the rear. The supercharger was, as before, placed on the side of the crankcase but it now aspirated through twin downdraught carburetters, in place of the earlier single updraught instrument, the fuel/air mixture being discharged downwards from the blower and then passing through a right angle through a vertical riser pipe which joined a simple eight-branch manifold.

The whole power unit was set low in the frame so that the centre line of the transmission was substantially below that of the half shafts there being a double reduction gear included in the rear axle housing. The separately mounted four-speed gearbox with short open propeller shaft and right-hand driving position were in accordance with Bugatti tradition, but after some ten years of successful use Bugatti abandoned the cast aluminium wheels in favour of a very unusual arrangement of wire wheel in which the rim had internal serrations engaging with teeth cut on the periphery of the brake drum. This resulted in an extremely light assembly and changing the wheel continued to expose the brake shoes. These were expanded by levers operated by the

brake cables of the exposed type running over pulleys which had characterised previous designs.

After another unsuccessful appearance at Monaco in April, 1934, Bugatti bored out the cylinder block from 68 to 72 mm., thus bringing the capacity up to 3.3 litres or rather over 10 per cent more than the rival Italian models.

From the technical viewpoint all three constructors who had been racing continuously for the past five years were using entirely othodox designs and indeed the bulk of the parts in the Italian cars were interchangeable with models built in the previous year.

As had been briefly mentioned in Chapter 2 the German cars constructed by Auto Union and Mercedes-Benz represented a complete departure from anything which had hitherto appeared on the starting line of an international race, but in detail design the Mercedes-Benz engine remained a traditional Stuttgart production. That is to say, it had welded steel cylinders, four valves per cylinder inclined at 60 degrees, roller-bearing crankshaft and big ends, and a supercharger supplying pressure air to the carburetters.

As explained in Example No. 14, Volume I, the blower was continuously coupled to the engine, the degree of boost being controlled by an inter-connected intake throttle and pressure release valve.

In detail the engine showed some variations from normal straight-eight practice, particularly in the use of five main bearings per crankshaft, and in the crank angle and firing order, but the most startling feature was its size and power output. Within an all-up weight of 450 lb. the designers contrived a bore and stroke of 78 x 88 mm., a capacity of 3.66 litres rising, within the first racing season, to 82 x 88 mm. (3.71 litres) and 82 x 94.5 mm. (3.99 litres). The smallest variant gave 354 b.h.p. on alcohol fuel. The first stage of enlargement raised the power to 398 b.h.p. and before 1934 was out the biggest version of the three was giving 430 b.h.p.

Never before in the history of motor racing had there been so large a step forward in maximum power available for the road wheels, and the gain of 125 h.p. as between the 1933 205 b.h.p. Maserati and 1934 Mercedes-Benz was greater by 10 h.p. than the entire gain in racing engine power output between 1906 and 1933.

Barely stated in this fashion one might be led to believe that the 1934 Mercedes-Benz power units had some miraculous combination of boost and r.p.m., but a study of their design shows that they were basically similar to earlier types of engine and may in fact be logically considered a direct development from the designs of the mid-twenties which also used steel cylinders and full roller-bearing crankshaft assemblies. Having previously used the 1926 eight-cylinder 1½-litre Talbot as a yard-stick to measure the efficiency of the P3 Alfa Romeo we can profitably make a similar comparison between the former engine and the Mercedes-Benz as it was run in the mid-season of 1934. If we do this we have the following :-

	1926 Talbot	*1934 Mercedes-Benz*
R.P.M.	6500	5800
Piston Speed ft./min.	3230	3600
H.P. sq. in. Piston area	4.68	5.9
B.M.E.P. lb. sq. in.	194	236
Manifold Pressure Ata.	1.95	1.66
H.P./Litre	96.6	105.5

The Mercedes-Benz figures for r.p.m., piston speed, manifold pressure h.p. per litre, cannot be reckoned as outstanding but the results under the heads b.m.e.p. and h.p. per sq. in. are remarkable, particularly bearing in mind the moderate boost pressure employed.

As has been pointed out in previous chapters the four valves per cylinder head has an inherent advantage in respect of valve area but on most previous designs this has been offset by impaired flow values. Mercedes-Benz engines were, however, remarkable for making the best of both worlds in this respect and it must not be forgotten that they enjoyed far more overlap than previous types. The resultant value of 17.7 h.p. per sq. in. of inlet valve area was 27 per cent better than the contemporary Alfa Romeo using nearly the same boost pressure.

Having given due credit to such detail refinements in a comparatively normal type of engine we must recognise that the primary technical interest of the car resides in the use of independent suspension to all four wheels.

In the early days of racing, Bollée and Sizaire-Naudin had used independent suspension on the front wheels of their voiturette cars but the nearest approach to independent suspension for the rear wheels had been in the chain driven models built in the first ten years of racing. In these the rear axle beam was relieved from transverse torque, and the consequent liability of one wheel to lift and spin. The use of a separate drive to each independently sprung rear wheel was, however, entirely a post-war development, pioneered by Prof. Rumpler and developed for racing only by Benz who used the swing axle arrangement on their 1923 six-cylinder, rear-engined cars which ran in the Italian Grand Prix and afterwards competed with some success in sports car form in various German national races and hill climbs.

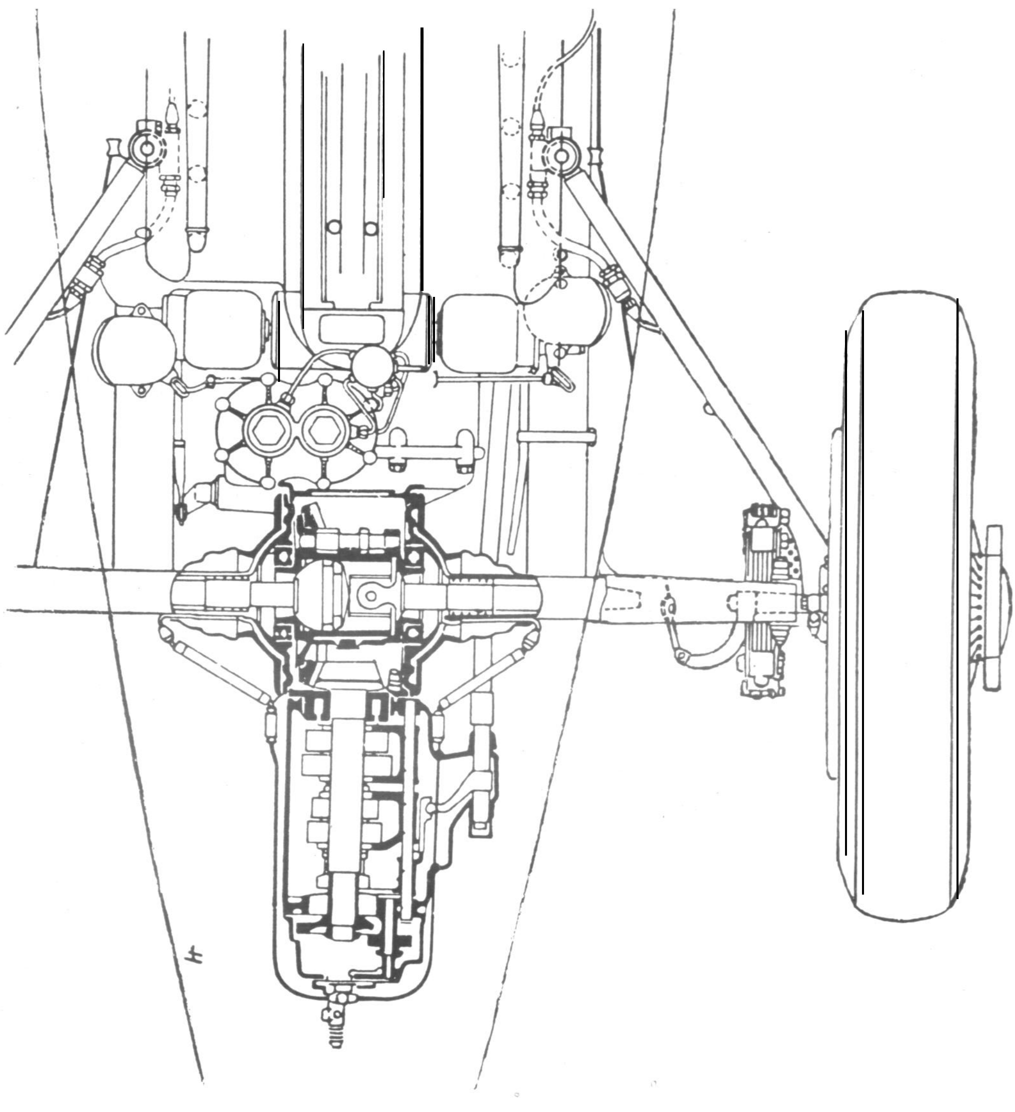
When Mercedes and Benz amalgamated in 1926 this model was discontinued but Ledwinka continued the development of the swing axle with Tatra in Czechoslovakia. He additionally used independent front wheel springing and Tatra having proved the advantages thereof for low powered cars over very rough roads Mercedes-Benz followed with two small cars of 1½-litre capacity, one of them with rear engine mounting. Thus the decision to use all independent wheel suspension for the 1934 racing cars was a case where production car design influenced that of the competition model and not vice versa. But the actual application of principle to the Type W.25 was based on arguments strictly relevant to high speed performance. For example, no great effort was made to provide large wheel movements as clearly shown by the use of short transverse quarter-elliptic springs at the back of the car.

As mentioned in Example No. 14, Volume I, the overall length of the spring was only 14 in., and the maximum wheel travel was barely 2 in. The swinging half axles containing the driving shafts were held in trunnion bearings and thus although vertical movement produced a corresponding angular change there was no variation from the parallel if the car was viewed in a vertical plane. The springing of the front wheels also provided little increase in vertical movement compared with the orthodoxly sprung types the full bump position being barely 2 in. above the normal loading position. The benefits derived from I.F.S. were, however, not wholly bound up in the matter of increased wheel movement. Perhaps more important was the fact that the elimination of axles meant that the disturbance of any given wheel was not transmitted to its fellow whilst the elimination of torque effect at the back of the car was beyond doubt a very powerful factor in countering wheel spin and in giving abnormal acceleration away

from low speed corners. All of these arguments in favour of independent suspension applied in equal measure to the Porsche-designed Auto Union cars which, in common with Mercedes-Benz, had parallel moving front wheels and swing axles at the back. The mechanical arrangement at the front differed, however, each wheel being supported on two trailing arms and torsion bar springs giving it a deflection of 1 in. per 350 lb. At the rear a single transverse spring was mounted some 30 in. above road level and torque reaction was absorbed by radius arms running forward to ball joints fixed to the tubular frame members.

These arms were placed at an angle of 57 degrees and the axis of wheel oscillation lay between the centre line of aspherical bearings on each side of the bevel box and the centre point of the ball and socket joints on the frame. With this arrangement there were variations of both track and toe-in as the wheels rose and fell.

Both the Mercedes-Benz and Auto Union cars had a roll centre at ground level at the front and considerably above hub level at the rear so that in both cases the anti-roll couple at the back was considerably higher than it was at the front.



Rear axle and gearbox layout of the Auto Union.

We have remarked previously on the boldness of the Mercedes-Benz engineers in raising engine output by 100 b.h.p. over 1933 figures and committing themselves to a chassis with all independent suspension. The Auto Union amalgam was even more audacious in that it also embraced a V. 16 engine of quite exceptional piston area mounted between the driver and the rear wheels.

The possibility of using rear engine mounting had been considered by Mercedes-Benz and both Nibel and Wagner (who were largely responsible for the chassis design of the Stuttgart products) were ex-Benz men who had had personal experience of the 1923 racing cars. This notwithstanding they concluded that the conventional engine position was the better. In making the opposite decision Porsche was undoubtedly influenced by his business partner, Adolf Rosenberger, who had been a successful competitor with the rear-engined Benz sports cars in 1925. General interest in the rear-engined cars had also been revived in 1930 by an article by Joseph Ganz in Motor *Kritik* which dealt specifically with the Benz racing cars built six years previously.

Porsche considered that two contemporary considerations of 1934 racing added special merit to rear engine location. The prospect of growing engine power and size involved provision for more and more fuel unless average speeds were to be marred by unnecessary pit stops (i.e. stops, dictated solely by the need to refuel over and above those required for fitting new wheels and tyres) and a big tank at the back of the car could impair road holding.

The maximum weight enforced by the 1934 regulations was another incentive since the elimination of the propeller shaft and the combination of engine, gearbox and bevel box in one aggregate was undoubtedly a weight saving factor. These were no mere theoretical considerations. The change in weight as between the front and rear wheels with a conventional tank arrangement as compared with the central tank adopted by Auto Union has already been mentioned and, further, so far as all-up weight is concerned, the Mercedes-Benz cars as first built had the utmost difficulty in complying with the regulations, but Auto Unions had many lb. to spare. This was remarkable in that although the power of the two cars was almost the same the cubic capacity of the Auto Union engine was no less than 4.36 litres, whilst the piston area of 90 sq. in. was 50 per cent more than the Mercedes and approximately twice as much as the corresponding Alfa Romeo. Another useful advantage (accruing from the abolition of propeller shaft) was a reduction in overall height and frontal area although in comparing the latter figure with, say, the Alfa Romeo it must be borne in mind that both the German cars resorted to a good deal more cowling on the grounds that the larger projected area was balanced by lower drag co-efficient. It is interesting to make a table of broad specifications of the principal rivals in the early part of the 1934 season. These were :–

	Alfa Romeo	*Auto Union*	*Mercedes-Benz*
No. of Cylinders	8	16	8
Cylinder arrangement	In line	V 45°	In line
Cubic Capacity, cm.^{3}	2900	4360	3360
Maximum b.h.p.	210	295	354
Frontal area	10.8	10.8	11.8
H.P. per sq. ft.	19.5	27.3	30
Laden weight	18.7	21.5	20
B.H.P. per laden ton	225	263	354
Maximum speed, m.p.h. . .	145	170	165

As shown in the table on page 82, Volume I, Maserati ceased to be an effective force in formula racing in 1934 and in 1935 Bugatti also faded out and failed to secure a place in any of the major European races, so from a technical viewpoint interest was concentrated on Alfa Romeo, Auto Union and Mercedes-Benz. In all three cases the most noticeable change compared with the previous year was the introduction of more power. Alfa Romeo increased the cylinder diameter of the P3 engine to 72 mm. bringing the capacity up to 3.2 litres ; Auto Union bored out their sixteen-cylinder engine to 72.5 mm. diameter bringing the capacity up to 4.95 litres. They also raised the manifold pressure from 1.6 Ata to 1.75 Ata and the compression ratio from 7 : 1 to 8.95 : 1. By these changes they combined a bigger engine with both higher b.m.e.p. and maximum r.p.m. so that they developed 375 b.h.p. at 4800 r.p.m. Mercedes-Benz for most of the year used an engine of 3.99 litres capacity giving 430 h.p. at 5800 r.p.m. The general performance factors were therefore :

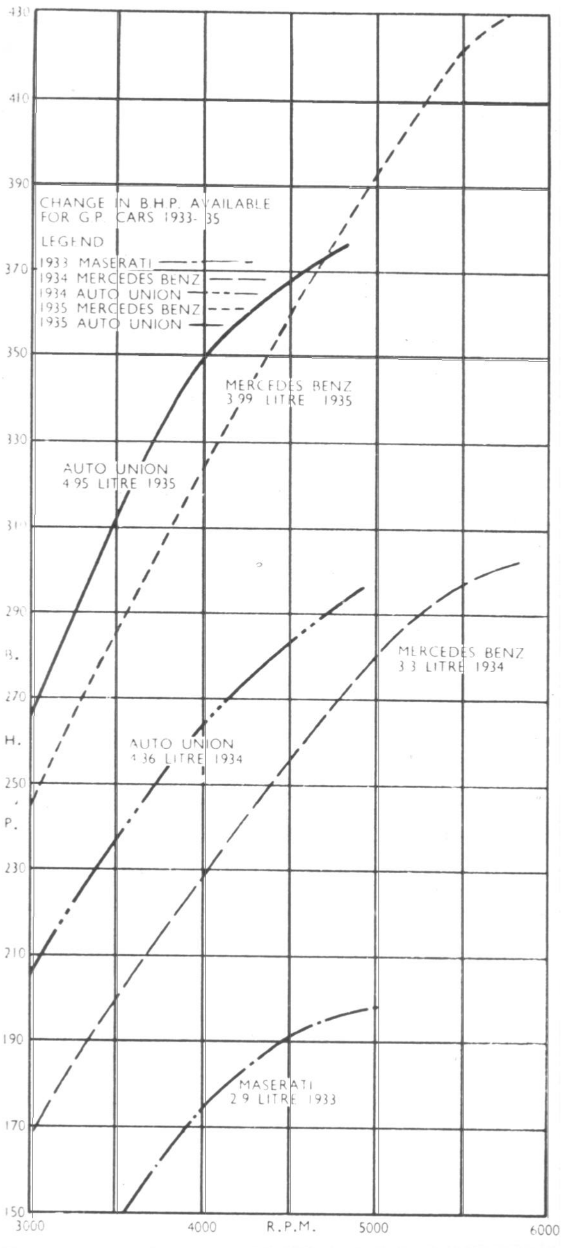
	Alfa Romeo	*Auto Union*	*Mercedes-Benz*
No. of Cylinders	8	16	8
Cylinder arrangement ..	In line	V.45	In line
Cubic Capacity $cm.^3$ ..	3200	4950	3990
Maximum B.H.P.	262	375	430
Frontal area	10.8	10.8	11.8
H.P. per sq. ft.	24.2	34.6	36.5
Laden weight	19	21.5	20
B.H.P. per laden ton ..	275	350	430
Maximum speed	155	175	180

The maximum speeds cited above are, as in the 1934 table, theoretically derived from the b.h.p. per sq. ft. figures. Fortunately, however, in this year we have a direct check between calculation and reality at Pescara where Alfa Romeo reached 157 m.p.h. and Auto Union 172 m.p.h.

In view of the overwhelming success of Mercedes-Benz in the races of 1935 it is only reasonable to suppose that it was the fastest of the three cars, although it did not run at Pescara and was not timed in any other race.

In addition to increasing engine size and output both Alfa Romeo and Auto Union made a number of chassis changes. The former adopted independent front wheel springing using the Dubonnet scheme and also hydraulically operated front brakes. A number of cars were built and run with reverse quarter-elliptic springs on the Bugatti principle attached to the normal P3 Type twin propeller shaft rear axle. Auto Unions made considerable changes on their car, the tail was shortened, the exhaust manifolds modified, and perhaps most important of all the transverse leaf spring removed and in its place torsion bars fitted inside the tubular frame members connected to the swinging half shafts by short arms and links. The geometry of the system remained unchanged but the spring rate was decreased to 230 lb. per in. so that the rear suspension was now substantially softer than the front.

Apart from minor changes based on the racing experience of the previous year, the Type W.25 Mercedes-Benz chassis and body-work remained unaltered.



But although during 1935 the difference in between the ultimate development of the classic car, as exemplified by the Alfa Romeo, and the heterodox types was a mere ½ per cent, the future was to show that the last ounce of performance had been wrung out of the former whereas the latter were to prove capable of even further developments in the realms of power and speed.

CHAPTER EIGHTEEN

Peak Performance

THE German road racing cars of 1936 and 1937 had more power per sq. ft. and per ton, and correspondingly a higher maximum speed and greater acceleration than anything hitherto known. It is, in fact, no exaggeration to say that the sheer statistical performance of the C Type Auto Union and the W125 Mercedes-Benz is unlikely again to be equalled by cars using piston-type power units. As a corollary, the gap between these cars and Alfa Romeo became even more pronounced than in 1935, and all other makes definitely dropped out of the running.

These facts should not result in any understatement of the merits of the Alfa Romeo cars which represented a very material improvement on previous models of the marque.

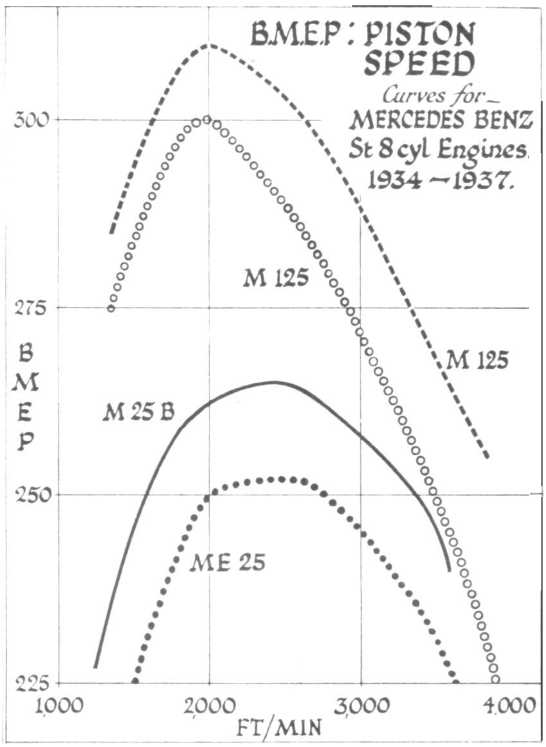
As has been mentioned in the previous chapter the Alfa Romeo which won the 1935 German Grand Prix run in July followed the innovation of the previous year by using independent suspension for the front wheels. This was an adaptation of an existing chassis design, but in September, 1935, the Milan factory produced an entirely new machine, which in addition to having a 3.8-litre, straight-eight, engine, had independent suspension to all four wheels, the arrangement at the rear consisting of a swing axle with a transverse leaf spring. Using this car Nuvolari made the fastest lap of the day at 90 m.p.h. at Monza, and although the model was less successful in the succeeding Spanish Grand Prix, both the designer, Jano, and the drivers were well pleased with the stability and road holding. One may suppose that this engine developed at least 330 b.h.p., whereas the P3 in its most highly developed form gave no more than 265 b.h.p., and thus the prospects for 1936 seemed bright.

As with the P3, so with the new car, outstanding performance was realised in relation to the comparatively low power, and this all-independent Alfa Romeo gained many successes during the 1936 season, winning five events, one of them in the U.S.A. In the latter part of the year the car was run with a twelve-cylinder engine of four litres capacity developing some 360 b.h.p., and in this form gained second position in the Italian Grand Prix.

It will be seen that the Italians recovered considerably from their series of defeats in the latter half of 1934 and (with one major exception) the whole season of 1935.

For Mercedes-Benz 1936 was a lean year indeed, and this is all the more surprising since the Stuttgart engineers enlarged the capacity of the straight-eight engine (Type M25E) to 4.74 litres and extracted 494 b.h.p. at 5,800 r.p.m. from it. In addition, a very considerable change was made to the body and chassis design. The former was far more curved than previously, with fairings built over the suspension units. The front springing arrangements remained as before, but modifications were introduced at the back to cope with the greatly increased engine power. And, most important of all, the wheelbase was reduced by 11 in. in order to meet the demands of the drivers for a more easily-handled car on short and twisty circuits.

This short-wheelbase model had been used for practice in all the later events of 1935, and it started the 1936 season promisingly enough with two wins-Tunis and Monaco. However, during the rest of the season it only once secured better than a fourth place, a sad change from the victories of the previous year. Mechanical troubles played their part in this unhappy result, but the car proved its speed not only in winning the races just mentioned, but also by making fastest lap at Berne in practice for the Swiss Grand Prix and leading in this event for the first eight laps. At Tripoli, however, this car proved no faster than the 1935 model, whereas, on this exceedingly fast circuit, the 1936 C Type Auto Union proved itself to be 3½ m.p.h. quicker than the previous B Type model.



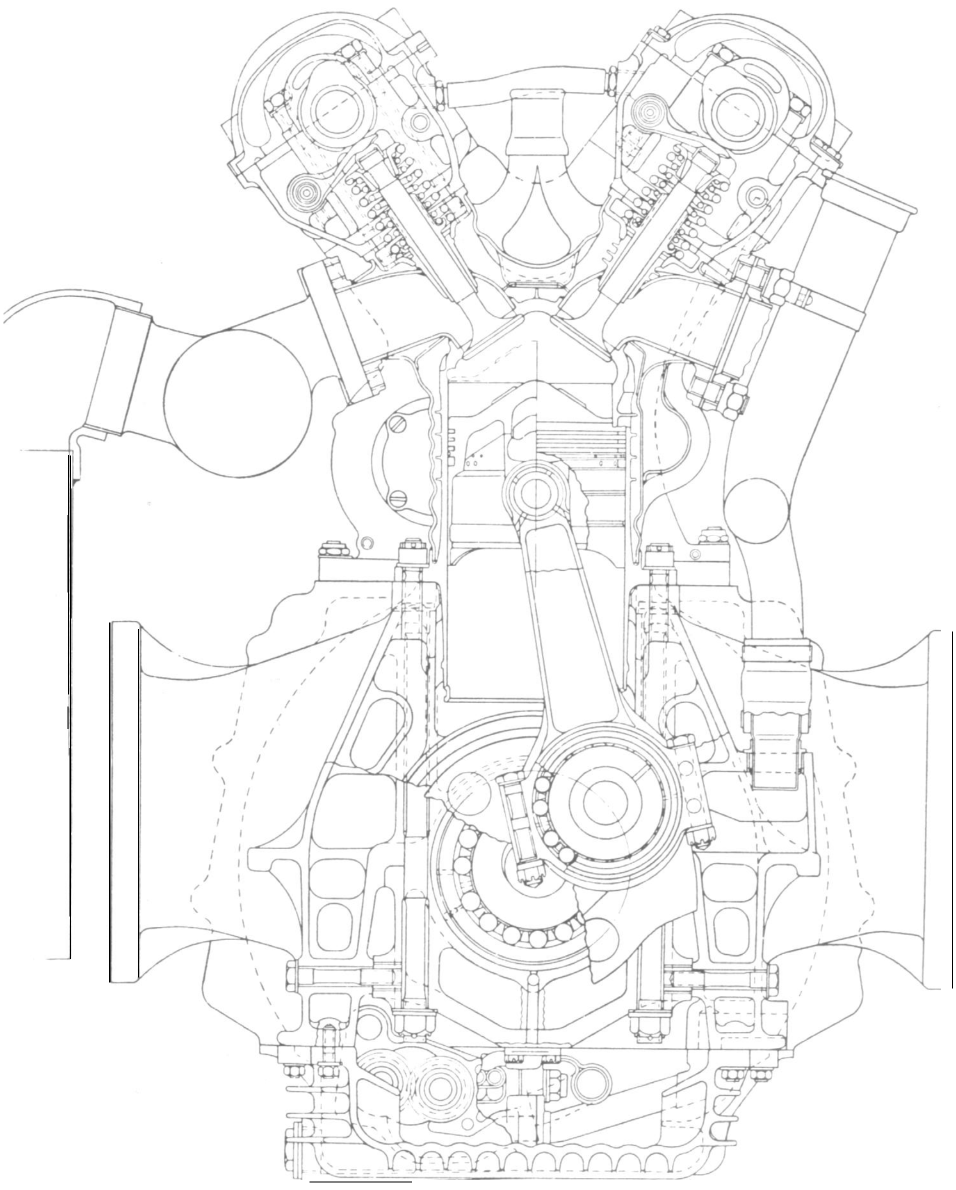
Curves showing the fall in b.m.e.p. as the five-bearing Mercedes-Benz engine had enlarged swept volume with fixed valve size ; and the improvement effected on the 1937 seven-bearing engine especially with special carburetter.

Auto Union, in contrast to Mercedes-Benz, lengthened their wheelbase in 1936 by 4½ in. and simultaneously increased the track by 1 in. The extra length was given up to a 46-gallon fuel tank, for although the engine capacity was raised by over 20 per cent to 6 litres this was achieved within the framework of existing castings and cylinder centres.

The bore was increased only from 72.5 mm. to 75 mm., the stroke being lengthened from 75 mm. to 85 mm. as compared with the 1935 B Type car. Simultaneously the compression ratio was raised from 8.95:1 to 9.2:1, and the boost pressure from 1.74 Ata to 1.87 Ata. These changes took the peak r.p.m. up to 5,000, so that with a b.m.e.p. of 330 lb. per sq. in., 520 h.p. was attained. Despite this great gain in power both weight and frontal area remained unchanged and, compared with the P3 Alfa Romeo constructed only four years previously, b.h.p. per ton was doubled and power per sq. ft. nearly trebled.

In these circumstances the maximum speed in a race was determined more by choice of gear ratio than by available power, but with the highest gear the car could reach a theoretical 210 m.p.h.

With the same gearing the curves of tractive resistance against torque available in the various gears show that full power would give wheel spin on first and second gears up to 100 m.p.h., and that on wet roads the wheels would spin at any speed below 175 m.p.h. if the engine were given full throttle. With the lower rear axle ratios used for road racing, maximum speed at peak r.p.m. would be reduced to some 180 m.p.h., but the torque curves would lie some 20 per cent higher than those shown on the graph. In other words, the curve of tractive effort on fifth speed would lie approximately on the line occupied by third speed in the graph and third would correspond with the graph for second speed. It will be seen that in this case full throttle would give wheel spin between 50 and 125 m.p.h. even on a dry road (*vide* page 143).



The 5.66-litre 8-cylinder Mercedes-Benz engine of 1937 (Scale 1 : 4).

Performance of this kind obviously taxed the driver's judgment to the utmost, and the great power also exaggerated the inherent over-steer characteristics of the suspension system. These facts, coupled with the forward seating, made it necessary

to choose a driver with abnormally quick reactions and to provide him with very direct acting steering. Brakes also became a critical problem and tests showed that they were in use for up to 35 per cent of the total distance of any race.

From the inception of the 750 kg. formula both Auto Union and Mercedes-Benz had used Lockheed brakes with drums approximately 16½ in. diameter and 2 in. wide which were as large as reasonably possible, even with the very big wheels which were being used. Braking, however, was improved on the 1936 Auto Union C Types by having two leading shoes and by using ventilating scoops to keep the temperature down to a minimum. Light alloy drums with inserted liners were, of course, employed and there were also two master cylinders connected by a balancing lever which permitted a quick variation of brake distribution as between front and rear wheels. This scheme guaranteed that one set of brakes would always work in the event of pipe failure, but such a breakdown was, in fact, never experienced.

Despite the enormous power available road consumption remained reasonably good at between 3½ and 4½ m.p.g., this being a reflex of the very creditable specific fuel consumption obtained with the V16 engine which averaged between 0.77 and 0.88 lb. per b.h.p. hour. As the 2- to 3-litre cars used prior to the 1934 formula had given 6 to 8 m.p.g. with not more than 200 b.h.p., 4 m.p.g. with over 500 b.h.p. can be considered a most excellent performance.

The figures above mentioned enable one to calculate the approximate average power used throughout the circuit. At an average of 90 m.p.h. fuel was being used at the rate of some 25 gallons per hour, and if one takes the consumption at 1 pt. per b.h.p. hour there is an average engine output of 200 b.h.p. This at the full laden weight was the equivalent of 180 b.h.p. per ton.

Tyre consumption proved to be an even more difficult problem than fuel consumption. Prof. Dr. Ing. Eberan von Eberhorst has produced some most interesting figures showing the tyre life to be expected on the Nürburg Ring in relation to average lap speed and this, tabulated, is as follows :

Average Speed		Tyre Mileage
72½ m.p.h.	.. ..	620
75	.. ..	360
77½ ,,	.. ..	220
80 ,,	.. ..	175
82½ ,,	.. ..	120
85 ,,	.. ..	100

Even these comparatively brief mileages postulated the use on the rear wheels of exceptionally large tyres of 7 in. section mounted on 19 in. rims. Even larger wheels with 22 in. rims were used for exceptional events such as Tripoli and A.V.U.S. These were designed by Continental to run at comparatively high pressures, that is to say up to 60 lb. on tracks and 50 lb. on road circuits, maximum tyre temperature was kept down to 85° C. Four tyres weighed 158 lb., equal to nearly 9 per cent of the unladen weight.

The rear tyres were larger than the front and one may assume that each rear wheel and tyre weighed nearly 60 lb., so that the unsprung rotating masses represented by the tyre, wheel and brake drum scaled at least 80 lb. With masses of this order the acceleration with one back wheel striking a bump at 180 m.p.h. could provoke a gyro-

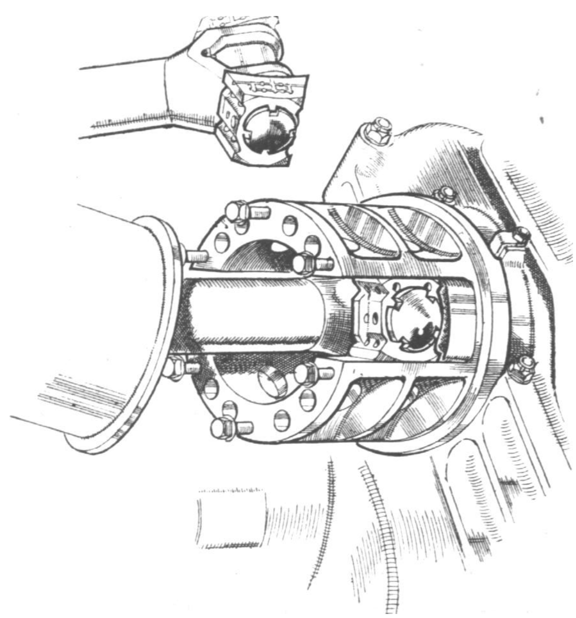
scopic reaction of the order of 1,000 lb. ft., and as the Auto Union geometry imposed a change of toe-in as well as " pendel " motion around the swing axle points it can readily be seen that at high speeds, even on the straight, the cars could be unstable.

During 1936 Mercedes-Benz decided to embark upon an entirely new design of racing car. Produced by the same team of engineers (that is to say Director Max Sailer as head of the experimental department with Oberingenieur Wagner and Hess looking after chassis and engine respectively), who had been in charge since the death of Nibel, it represented as complete a break with the previous W25 series as the former had with the previous " classic " design of car.

It has been truly said that " the courage of the pioneer lies not so much in doing something new as in saying farewell to something old. The design of the WI25 was a complete "farewell " in that no major part of the previous cars was carried forward. The car is fully described as Example No. 16, Volume I, and from a technical viewpoint it was remarkable for it led the way to really soft suspension, it was the first road racing car to employ the de Dion type of rear axle and, finally, it was the first, and only, road racing car having a power unit which developed over 600 b.h.p.

In the first three seasons of the 750 kg. formula racing, independent suspension to all four wheels had been used in conjunction with comparatively stiff springs, giving, on the front wheels of the W25, a vertical rise of only 2 in.

On the 1937 W125 design the front wheels were permitted to rise 3 in. from normal to full-bump position, and the rear wheels nearly 4½ in., and in order to provide this increased motion at the front end of the car the effective length for the wishbones was increased from 5 in. to 10 in., and the short, stiff, enclosed coil springs replaced by large diameter open coil springs. In addition, the friction-type shock absorbers were replaced by hydraulic dampers which was in harmony with the theme of reducing the stiffness of the suspension. At the same time the work imposed on the dampers was, of course, immensely increased by virtue of the greater wheel motion and only a marked step forward in the design of piston-type fluid dampers made this change possible.



The 1937 Mercedes-Benz Type WI25 had a de Dion type rear axle with exposed half-shafts, each with two universals. Splines were avoided by the use of de Dion pot-type joints shown in this drawing. The design was unchanged for 1938 and 1939.

In the designing of the rear suspension of the W125, Wagner followed the move made by Porsche in 1935 in substituting torsion bars for a transverse leaf spring, thereby decreasing both the stiffness of the suspension and the weight of the spring itself. More important, he threw away independent suspension with swing axle at the rear and substituted a de Dion layout and by this stroke entirely changed the handling characteristics of the racing car. For the first time absence of torque reaction tending to lift the right-hand driving wheel was coupled with freedom from gyroscopic reaction caused by the rear wheels swinging about a short radius, and although the unsprung weight was greater than with the swing axle it was far less than with the " classic " axle beam used up to 1934.

The Count de Dion commenced his career as an automobile manufacturer by producing steam cars to the designs of two engineers called Trepardoux and Bouton, and by the end of the nineteenth century the firm was known as de Dion-Bouton and concentrated entirely upon the production of petrol-driven cars and proprietary engines. Considerably earlier than this, however, de Dion had been interested in steam-propelled vehicles and actually drove one in the first motoring competition of which we have definite knowledge, which was run in 1887. In 1894 a de Dion steamer put up the fastest average speed (11.6 m.p.h.) in the Paris-Rouen run, and there is photographic evidence that in 1893 the idea of the de Dion axle had taken shape.

Since the layout was particularly suitable for use with a steam engine it has been suggested by Kent Karslake, that the idea may well have come from the drawing-board of Trepardoux. This is speculation, but it is a matter of record that the merits of this system for driving and suspending the rear wheels of racing cars was ignored until 1931 when it was revived by Harry Miller who used it on the three eight-cylinder 3.75-litre cars which he built for the Indianapolis race. One of these driven by Hepburn finished third but truth compels one to record that the use of this scheme was probably dictated more by convenience than by enlightened engineering.

In 1924, Miller had built some front-drive cars which had used in effect the de Dion axle for the front wheels. These were supported on a tubular axle beam and were driven through exposed half-shafts which had two universal joints on each side. Not all the racing drivers who were supplied with these cars were, however, satisfied with the front-drive principle and to meet their wishes a rear-drive chassis was built in which the front-end parts were used *en masse* at the back end of the car. It is interesting to note that although the Auto Union group adopted the de Dion layout for Horch touring cars of 1935 the scheme was not used in road racing vehicles until adopted by Mercedes-Benz in 1937.

Mercedes-Benz coupled these radical changes in suspension with a frame of remarkable stiffness fabricated from welded steel tubes of oval section. By using material less than 2 mm. thick, weight was reduced to a minimum, and although the wheelbase of the W125 was increased by 3 in. compared to the 1934-5 models (1 ft. 1 in. compared with the 1936 car), the dimensions of the brake drums increased, and the rear axle assembly improved, the chassis weight rose by only 33 lb.

A larger engine, of entirely new design and remarkable performance, added a further 45 lb. to the dry weight.

Ob. Ing. Hess had been in charge of the design of all Mercedes and Mercedes-Benz racing engines since 1914, and he continued to direct the construction of the

M125 power unit along the basic lines which had proved so successful for more than thirty years. In detail, however, the Ml25 was a great improvement on the M25 series. It had nine main bearings in place of five, crankshaft diameter was increased by 13 mm., and it was counter-weighted, the cylinder diameter increased from 86 to 94 mm. (the stroke remaining the same), and the capacity raised to 5.66 litres.

In 1936 the 4.74-litre ME25 engine was giving 494 b.h.p. (slightly less than the 520 b.h.p. of the 6-litre Auto Union) but in an early trial, using petrol-benzol as fuel, the Ml25 gave 545 b.h.p. maximum and 515 b.h.p. at only 5,000 r.p.m. Later tests on alcohol fuel showed 568 h.p. at 5,800 r.p.m. These outputs were obtained after the traditional Mercedes-Benz supercharging arrangement, that is to say, the blower supplied pure air under pressure to the carburetters, had been abandoned.

The theoretical defects of this arrangement have been made plain in Chapter 12, and it is somewhat surprising for Mercedes-Benz to continue with this principle for three racing seasons. In July, 1937, however, they commenced racing with cars having suction-type carburetters, previous development on the test-beds having shown that large gains in power were derived in the change-over, particularly in the lower part of the speed range. This is shown clearly in the curves for b.m.e.p. versus piston speed, which is limited to the relative performances of the M25 and Ml25 series of engines.

Taking into account the use of a special carburetter which increased the fuel flow to 2 lb. per b.h.p. hour on full throttle the gain in b.m.e.p. at full power was from 240 lb. to 262 lb. at 3,500 f.p.m. (13 per cent). At 2,000 f.p.m. the difference was as between 262 lb. and 310 lb. (18 per cent), a figure which compares closely with the 20 per cent gain obtained by a similar change in carburation layout on the 1924 Sunbeam engine for which curves are reproduced in Chapter 22.

It will be seen that the b.m.e.p. curves for all the Mercedes-Benz engines show a pronounced peak at about 2,000 f.p.m., corresponding to a little over 3,000 r.p.m. The Type Ml25 engine was thus remarkable not only for the colossal figure of 646 h.p. realised on the flywheel, but also on account of the tremendous power output at moderate r.p.m. For example, it gave 248 b.h.p. at 2,000 r.p.m.-almost the same power as achieved with the 1935 Alfa Romeo at little more than one-third the Italian car’s crankshaft speed. The power developed by the Auto Union’s engine at 5,000 r.p.m. was surpassed on the Ml25 at 4,000 r.p.m. The peak power was nearly 25 per cent greater than the C Type Auto Union, but this was offset to the tune of 16 per cent by greater frontal area. There remained, however, an advantage of 7 per cent in b.h.p. per sq. ft. of frontal area, and on these grounds one would expect the Mercedes-Benz to have a slightly superior circuit speed. Once again road speed mirrored the drawing-board.

The W125 scored not only in respect of sheer performance, but also in the matter of stability and ease of driving. The overall characteristics of the suspension and weight distribution made this car an inherent understeerer, a highly desirable quality in a racing vehicle, particularly one with great h.p. per ton, for in so far as the driver can provoke wheel spin he can immediately convert an understeerer into an oversteerer if the conditions require it. The Auto Union drivers, on the other hand, had no such option and were compelled to drive sensitive, oversteering, cars in which excessive throttle opening could produce most embarrassing results. Only Rosemeyer really mastered this problem, and it is instructive to make a table showing the com-

paratively large differences in speed between Rosemeyer and his team mates in the Auto Union stable in contrast to the homogeneous grouping of the Mercedes-Benz drivers.

Taking two diverse courses such as Nürburg Ring and Pescara as examples, we find that in 1937 Rosemeyer made the fastest practice lap on each. With him as a standard of speed we then get :

	Nürburg Ring	Pescara
Auto Union Team-Rosemeyer	100	100
Hasse	96	—
Müller . . .	95.8	—
Stuck	92.2	95.8
Fagioli	—	93.6
MerLedes-Benz Team-Lang	99	—
Von Brauchitsch : :	99	96.6
Caracciola . . .	97	96.6

In sum, taking the average of these two circuits, Rosemeyer was 4 per cent faster than Müller and Stuck, but Brauchitsch was only 1 per cent quicker than Caracciola and the biggest spread between the three fastest men of the Mercedes-Benz team was only 2 per cent.

Both makes of car, however, stand on the very peak of performance and this technical virtuosity was backed up by a tremendous organising effort to ensure supplies of fuel, tyres, spares and maintenance. In both teams, for example, it was usual to take two sets of cars to an event comprising cars to be used in the actual race, plus spare cars for practice only. In addition, there would be other cars undergoing overhaul at the works in preparation for an event taking place perhaps only a week subsequently. As mentioned in Chapter 13, Mercedes-Benz, for example, had the first call on the services of 300 tool-room men, and although these were rarely called upon to work all at once they constituted a source of skilled man-power which enabled new designs to be turned into metal, tested and approved or rejected in a remarkably short space of time.

The general atmosphere of team racing in this period has been faithfully portrayed in *Motor Racing with Mercedes-Benz,* by George Monkhouse, and from a technical point of view it is only necessary to remark that the successful running of the Stuttgart cars in particular was entirely dependent upon a highly developed service organisation.

By contrast the Auto Unions were far more lightly stressed. They ran at 25 per cent less piston speed and 10 per cent lower b.m.e.p., and thus could be, and probably were, run with a greater economy of means. The Mercedes-Benz was indubitably the faster car of the two, but one is bound to record admiration for the simple and harmonious Auto Union design which was able to compete successfully in four seasons of racing with no major changes.

The end of 1937 saw the end of the 750 kg. formula and the Donington Grand Prix of that year was the last public appearance of the world's most powerful racing cars. Practice speeds confirmed the slight superiority of Mercedes-Benz, but it was perhaps a happy accident that during the race proper these two makes tied for the fastest lap of the day.

CHAPTER NINETEEN

Technical Victories

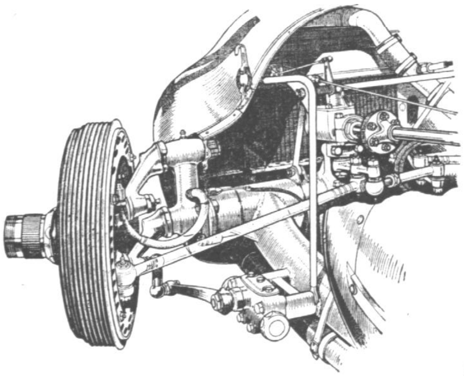
AS explained in Chapter 13, at the end of 1936 the 750 kg. maximum weight formula should have been replaced by new regulations in which minimum figures for weight were related to engine capacity.

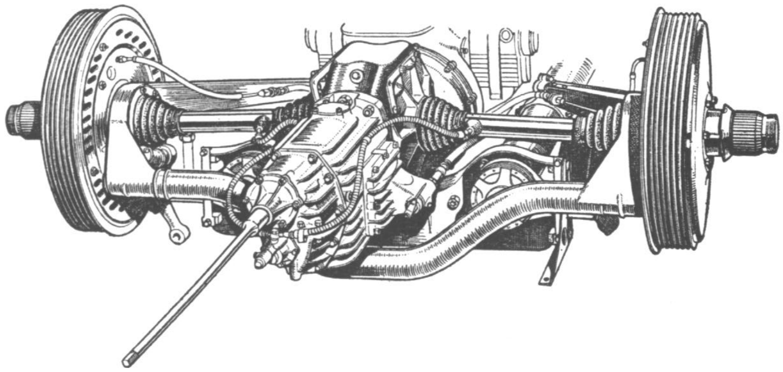
As a racing car has certain fixed items of weight and windage it was fairly obvious that all serious manufacturers would use the largest engine size permitted and after a good deal of discussion, during which it was proposed that a 4½-litre unsupercharged engine should be as effective as a 3.46-litre supercharged type, the maximum capacity for the latter was cut down to 3 litres ; simultaneously the change was deferred until 1937.

In 1935-6, when the matter was being argued, supercharged engines were developing about 235 b.m.e.p. at a piston speed of 3,500 f.p.m., and there was an implied assumption that the designer of an unblown engine could extract 157 b.m.e.p. at the same piston speed. Prima facie this was a logical contention, but two highly important factors were overlooked. The first, that by raising the boost pressure, the designer of a supercharged engine had a ready means of increasing b.m.e.p., whereas 160 b.m.e.p. might be considered as the ultimate on an engine with atmospheric induction. The second, that to maintain parity of performance piston area would have to vary directly with cylinder capacity. Logically, therefore, if the 3-litre supercharged engines were straight-eights the unsupercharged 4½-litre engines would be V12's, and it is worth noting that these types were adopted by Alfa Romeo and Delahaye respectively. Both Mercedes-Benz and Auto Union, however, chose to use V12 3-litre supercharged engines and, hence, secured an advantage in piston area over any unsupercharged type having fewer than eighteen cylinders. Moreover, both the German companies raised manifold pressure, Auto Union from 1.85 Ata (1937 C Type) to 2.2 Ata (1938 D Type) and Mercedes-Benz, also, from 1.85 Ata (W125) to 2.2 Ata (W154), increases of 22½ per cent. So far as the power unit was concerned they, therefore, met an enforced diminution of capacity by raising boost pressure and increasing crank speed by about 2,000 r.p.m. in each case.

These figures, coupled with piston areas of 61.5 and 65.5 sq. in. created maximum horsepower far beyond anything that could be possibly achieved by a twelve-cylinder, 4½-litre unsupercharged engine, and both technically and in performance on racing circuits the two German designs continued to dominate the field.

In the winter of 1937-8 major changes of personnel in the Auto Union camp substantially affected the design of the forthcoming cars. Porsche no longer continued as consultant and the responsibility for design was taken over by Director Werner, assisted by Ing. Fueureisen and Prof. Dr. Ing. Eberan von Eberhorst. Then in February, 1938, an accident during a record-breaking attempt caused the death of Bernd Rosemeyer, a most serious loss for he was not only a driver of genius, but also a capable mechanic able to act as a liaison between the design department and the team of drivers.





The 1938-9 Auto Union 3-litre cars had Porsche-type trailing link I.F.S. with a divided track rod. The rear wheels had de Dion suspension with exposed half-shafts and four Porsche universals.

It is no exaggeration to say that Rosemeyer's death pre-disposed the Auto Union group to retire from racing, but there were over-riding reasons that they should continue and they pressed on with work on the new cars in which, despite the departure of Porsche, the basic layout of the rear-engined C Type was retained. But with the exception of the gearbox and differential gear assembly all the components were changed in detail. The use of twelve in place of sixteen cylinders caused an increase in the included angle between the blocks from 45 to 60 degrees in order to keep even firing impulses, which in turn led to an entirely different valve gear for with the wider V it was no longer practicable to operate all the valves on a single central camshaft. In addition, the twelve-cylinder engine peaked at 7,000 r.p.m. and as the size and weight of the valves changed but little, inertia effects were double those on the C Type so that the previous layout was unsuitable for this reason alone. An ingenious compromise replaced it whereby the two inward facing inlet valves were operated as before by one central shaft (now carrying twelve cams) which in turn was driven from bevel gears and a vertical shaft at the back of the engine exactly as on the sixteen-cylinder Porsche design. This vertical shaft (also as before) carried spur wheels to drive the supercharger. At the top end, however, two short transverse shafts engaged with the bevel wheels carrying the drive to a camshaft mounted on the outside of each block which operated the exhaust valves. The similarity of the engines was continued further in the general layout which utilised detachable light-alloy heads and a deep crankcase with inserted wet liners, one-piece connecting rods and roller bearings for the big ends, and a Hirth crankshaft with lead-bronze main bearings having the same diameter as on the sixteen-cylinder power unit.

The crankshaft was, however, more fully counterbalanced so as to relieve the main bearings at the higher peak r.p.m., which in turn resulted in an output of about 420 b.h.p. as originally designed with single-stage boost.

As compared with the C Type engine both capacity and piston area were approximately halved, but piston speed was raised by 20 per cent and peak r.p.m. by

40 per cent. These were creditable achievements, but nevertheless the early 1938 D Type engines were deficient in power as compared with corresponding Mercedes-Benz Ml54 power units, and this made it imperative to increase the air flow per minute through the engine either by increasing r.p.m. or raising the manifold pressure.

The Auto Union engineering department always took a conservative view of crankshaft revolutions and presented with this choice they chose an increase in the boost pressure from 2.2 Ata to 2.6 Ata. At the lower figure the Roots blower was already giving a poor adiabatic efficiency and the higher pressure was thus conditional upon the use of two-stage blowing. This expedient was adopted in 1939 with the result that the engine delivered over 500 b.h.p.

The relative sizes and speeds of the blower units were as follows :

	D Type single stage Roots	Two-stage Roots blower	
		1st stage	2nd stage
Rotor length . . .	170 mm.	190 mm.	145 mm.
Rotor diameter . .	96 mm.	116 mm.	96 mm.
Rotor distance . . .	60 mm.	69 mm.	60 mm.
Delivery per blower revolution	1.385 litres	2.255 litres	1.180 litres
Ratio blower to engine speed	2.4	1.63	1.63
Boost	17 lb. (2.2 Ata)	12 lb. (1.8 Ata)	24 lb. (2.6 Ata)

For this two-stage engine a special carburetter was developed by Auto Union Racing Department and built by D.U.M. This had no float chamber, but four horizontal ducts with two jets in each. Each jet was fed with petrol by a pump and connected to a small over-flow chamber with surplus fuel scavenged by a second pump and fed back into the tank. This carburetter proved much more successful than float types, but an unexpected consequence of halving engine capacity was a very large increase in specific consumption, and as a consequence an actual reduction in mileage per gallon. The former rose from a maximum of 0.88 per b.h.p. hour on the C Type to 1.3 lb./b.h.p./ hour on the D model, and road consumption dropped from between 3½ and 4.7 m.p.g. down to only 2½ to 3½ m.p.g.

In order that the car could travel 150 miles on the track with a reasonable margin of safety a minimum tank capacity of sixty gallons was thus needed and the 3-litre cars carried sixty-two gallons compared to forty-six gallons on the C Type.

This greater volume was accommodated in side tanks with a central filler placed just behind the driver's head. The driver's seat was moved back a considerable distance on the frame as a result of eliminating the fuel reservoir which had previously existed between driver and engine, and also by reason of having twelve instead of sixteen cylinders. The basic principle of locating the tanks so that the trim of the car would not change as between the starting-line condition and mid-point during the race was retained, but the general handling characteristics of the D Type models were, however, noticeably different from the C Types of the preceding season.

This change was wrought by the use of a de Dion type rear end in place of the previous swing axle. Location sideways was by means of a transverse Panhard rod mounted barely 3 in. from ground level, thus bringing the rear roll centre down to the same height. The cross-tube had to be cranked downwards to clear the gearbox and necessary oscillation as between one side of the tube and the other was achieved rather more simply than in the case of Mercedes-Benz by having a floating bush adjacent to the left-hand wheel.

Both mechanically and geometrically the layout proved highly successful, but these benefits were achieved at the cost of considerable complication. Four Porsche universal joints were required for the driving shafts and twelve ball joints for various linkages, an interesting detail point being that all the Porsche joints were positively lubricated, the inner ones being within the differential box and the outer supplied by pressure oil delivered through the driving shafts.

The deflection of the rear springs was increased to 1 in. for a load of 175 lb. and was thus some 30 per cent softer than on the C model. A corresponding reduction in rate was given to the front wheels from 350 lb. per in. to 230 lb. per in. (52 per cent) and, simultaneously, the length of the Porsche-type trailing arms at the front was increased from 3.75 in. to 5½ in.

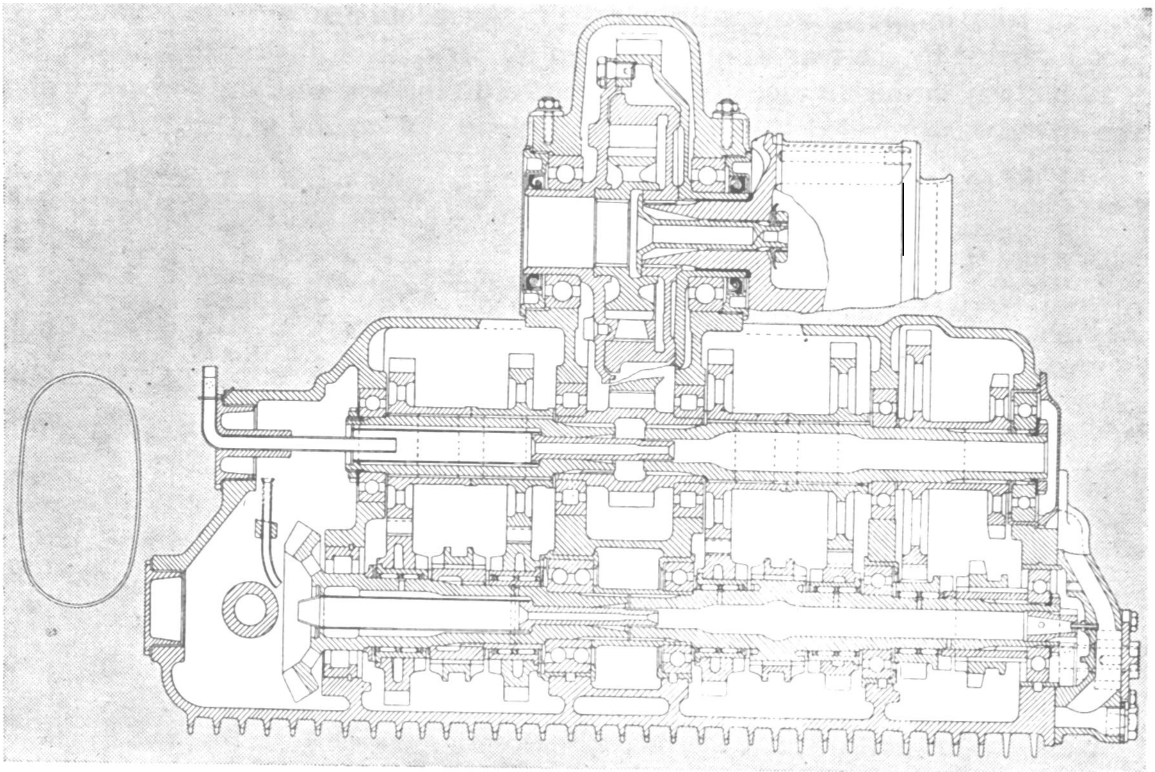
As before mentioned the geometry of the steering linkage on the C Type car was correct only with the wheels in the straight ahead position ; when they were on lock vertical motion resulted in considerable reactions being passed back through the steering box. The layout, as shown in a perspective drawing, was modified on the D Type with a view to providing correct geometry at all times.

The net result of all these modifications was to convert the Auto Unions from being pronounced over-steerers into being inherent under-steering cars, and on this score they could claim that in 1938-9 they inherited the basic stability which Mercedes-Benz achieved from 1937 onwards. Despite all these technical improvements, however, the D Type Auto Unions experienced a serious run of mechanical defects during their first season, and not until they had overcome these teething troubles during the 1938 season, and secured Nuvolari as their senior driver, were they in a position to challenge the Mercedes-Benz supercharged 3-litre cars which had the type number W154.

In 1938 Mercedes-Benz reaped the reward of having gone forward with a new chassis for the 1937 season, for as explained on an earlier page the W125 had been designed in 1936 to accommodate a 3.46-litre straight-eight engine, and it was, therefore, logical to use it as a base for the 1938 3-litre V12. As might be expected, a number of detail changes were made. Starting at the front of the car the position of the wishbones in relation to the wheel centre was modified and, going straight to the back, although the de Dion tube and suspension arrangements were virtually identical, considerable change was made in the transmission layout.

All the 750 kg. formula Mercedes-Benz employed a centrally placed propeller shaft, inclined downwards slightly, with an all-indirect drive to the half shafts. On the W154, however, the crownwheel and pinion was offset 10.8 in. to the left side of the car and the axis of the crankshaft was inclined both across the frame and downwards.

In addition Mercedes-Benz now decided to follow Auto Union practice of the previous years (and Delage of an even earlier date) by adopting five forward speeds.



General layout of five-speed gearbox on Mercedes-Benz (1938-9).

As shown in both drawings and photographs the propeller shaft now ran between the driver's seat and the frame members and the height of the car was thereby reduced from 41 in. to 34½ in. The wheelbase was also shortened by approximately 2½ in. and thus became almost identical with the length of the W25 series with which Mercedes-Benz had started racing four years previously.

The frame remained virtually unchanged from 1937, using deep oval tubes of chrome molybdenum steel.

As with Auto Unions, so with Mercedes-Benz, the very great increase in specific consumption following upon the use of a highly supercharged 3-litre engine posed serious problems of tank capacity. The Stuttgart Racing Department made serious studies for supplementary side-tanks carrying twenty-nine gallons but rejected this solution owing to the liability to damage should the car leave the road. As an alternative they decided to dispose of seventy-five gallons of fuel in two separate reservoirs, one in the orthodox position forming the tail of the car, the other in a saddle-tank fitted under the scuttle.

Owing to the comparative shortness of the V12 engine (which is clearly shown in a side elevation of the car) a reasonable amount of space was available between the steering wheel and the back of the cylinder block, and this forward tank was given a three-point mounting so as to isolate it from chassis distortion. One filler was used, the two tanks being inter-connected by large bore flexible pipes. Two windows were placed in the side of the body so that the mechanic controlling the pressure refuelling apparatus could watch the level rise and cut off just before the tank was full.

Despite carrying approximately half the fuel in the centre of the wheelbase there was, in contrast to the Auto Union, a side-tank arrangement, a considerable

change of trim in the Mercedes-Benz design. As mentioned on page 241, Volume I, the load carried by the rear wheels fell from 60 per cent on the starting line to 52-53 per cent halfway through a race and a rod control to the rear shock absorbers operated by the driver was provided to cope with this change of condition.

As the engine is fully described in Example 17, Volume I, it is unnecessary to deal with the details of its construction in this chapter. The overall position was, however, that although the capacity, compared with the Ml25 engine, was, by regulation, nearly halved the all-important piston area was reduced by only 24 per cent so that given equal b.m.e.p. and piston speed, viz. 252 lb./sq. in. at 3,400 ft./min., one would expect a conversion from 646 b.h.p. at 5,800 r.p.m. to 465 b.h.p. at 8,500 r.p.m.

Actually as first constructed the 3-litre engine gave 245 b.m.e.p. at 3,500 ft./min. despite the use of 20 per cent higher manifold pressure.

This shows clearly that the breathing of the engine was deteriorating somewhat due to the increase in r.p.m., and it is significant that at peak speed each sq. in. of inlet valve area was equal to 15.8 h.p., whereas the Ml25 engine had given 21.8 h.p. per sq. in.

In the course of development during 1938 the power of the Ml54 engine was raised to 476 b.h.p. at 8,000 r.p.m., the equivalent of 260 b.m.e.p. at 3,700 ft./min., but for the greater part of the 1938 racing season one may take it that the engine was giving approximately 450 b.h.p.

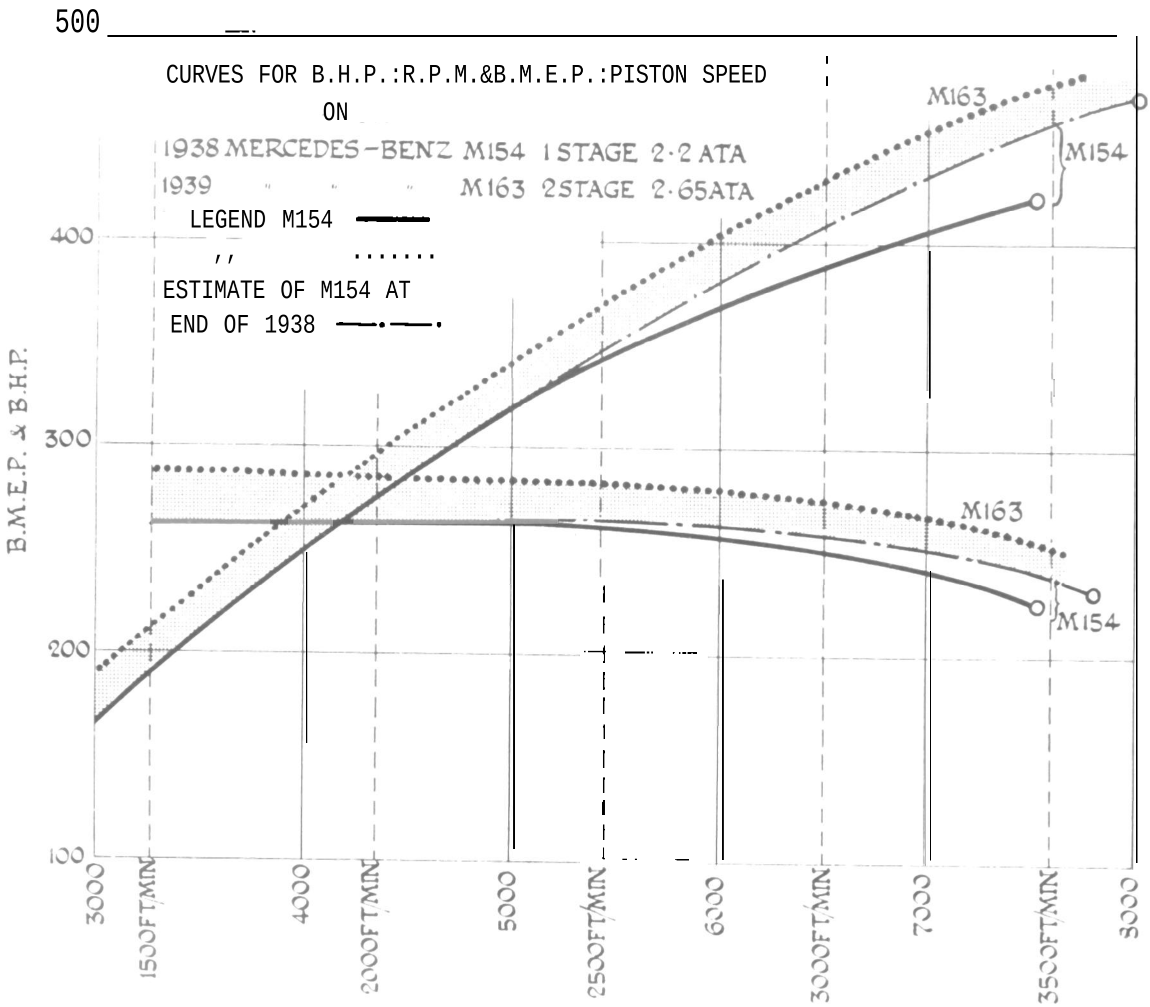
The 1938 car thus had some 200 b.h.p. less than the 1937 model and, contrary to one's first expectations, had the same frontal area as its predecessor and also weighed more. The V12, 3-litre engine alone weighed 72 lb. more than the straight-eight 5.66-litre unit, and the much larger gearbox and extra tankage brought the sum of the unladen weight up to 85 lb. more than the bigger car. Moreover, with seventy-five gallons of fuel the all-up starting line weight of the Type 154 came to 23.7 cwt., giving a figure of 380 b.h.p. per ton compared to 595 b.h.p. per ton for the W125. In addition, despite the reduction in overall height the frontal area was unchanged, so that the power per sq. ft. declined from 51.5 to 36 b.h.p.

In 1939 both Mercedes-Benz and Auto Union embarked upon two-stage supercharging and a number of minor chassis changes were also made by the former, the car having the new type No. W163. The engine weighed 45 lb. more than the Type M154 and the radiator was set very far forward from the cylinder block as shown very clearly in the side elevation drawing. The nose was simultaneously entirely altered in shape and the tail also modified, the total tankage being raised to eighty-eight gallons.

Perhaps the most important change of all, however, was the remarkable cooling system contrived for the brake drums which had considerable effect on the rate of retardation which could be exercised without incurring fade on one lap or excessive wear on the linings during the total distance of the race.

The Ml63 power unit gave only 4 per cent greater power than the final edition of the Type Ml54 at 7,800 r.p.m., but the valves would follow the cam contours up to 10,000 r.p.m., and between 4,000 and 7,500 r.p.m. there was a mean gain in b.m.e.p. of over 11 per cent as compared with the Ml54 as run at Rheims in 1938. This was derived not solely by increasing the manifold pressure by 20 per cent (from 2.2 Ata to 2.65 Ata) but also by considerable changes to the valve timing. The total inlet opening

was raised from 266 degrees of crank angle to 287 degrees, and the overlap about top-dead-centre enlarged from 61 degrees to 71 degrees. This change notwithstanding, the two-stage D Type 1939 Auto Union was slightly superior to the Mercedes-Benz m maximum power and substantially better in h.p. per sq. in. of piston and valve area.



STATISTICS FOR RACING CARS 1930-9

	1932 *Alfa Romeo*	1934 *Alfa Romeo*	1934 *Auto Union*	1935 *Mercedes-Benz*	1936 *Auto Union*	1937 *Mercedes-Benz*	1939 *Mercedes-Benz*	1939 *Auto Union*
Cylinders	8	8	16	8	16	8	12	12
Bore M/M . . .	65	69	68	82	75	94	67	65
Stroke M/M	100	100	75	94.5	85	102	70	75
S/B Ratio . . .	1.54	1.45	1.1	1.15	1.13	1.085	1.045	1.15
Engine Capacity CM^3	2650	2900	4360	3990	6006	5660	2962	2990
B.H.P.	190	210	295	430	520	646	483	485
R.P.M.	5400	5400	4500	5800	5000	5800	7800	7000
B.H.P. per litre . .	71.5	72.5	67.5	108	85.5	114	164	162
B.M.E.P. Lb./In.2 . .	172	175	200	242	230	256	270	305
Piston Speed F.P.M. . .	3550	3550	2220	3600	2900	3900	3600	3460
Piston Area sq.ins. . .	41	46.2	90	65	109.5	86	65.5	61.5
H.P. per sq. ins Piston area	4.65	4.55	3.28	6.6	4.75	7.52	7.4	7.9
Piston area sq. ins. per litre	15.4	15.9	20.6	16.3	18.3	15.2	22.1	20.6
Inlet valve area sq. ins.	14.8	14.8	23.7	22.5	23.7	29.6	26.5	16.9
H.P. per sq. ins. Inlet Valve area	12.85	14.1	12	17.7	22	21.8	18.3	28.6
Induction System . .	1.6 ata	1.6ata	1.6 ata	1.66 ata	1.87 ata	1.8 ata	2.65 ata	2.6 ata
Frontal Area sq.ft. .	10.25	10.8	10.8	11.8	10.8	12.5	12.5	11.5
H.P. per sq. ft. .	18.5	19.5	27.3	36.5	48	51.5	39	42.2
Weight cwt. unladen .	15.2	15.7	16,2	16.8	16.2	16.4	17.9	16.7
Weight with crew and fuel	18.2	18.7	21.5	20	22.4	21.8	24	24
Engine litres per laden ton	2.9	3.1	3.9	3.99	5.35	5.2	2.46	2.5
Engine B.H.P. per laden ton	210	225	275	430	430	595	405	405
Max. road speed ; m.p.h.	140	145	175	185	205*	195**	195*	195*

*These cars had five speeds.
**The maximum speed of these cars on a G.P. course was determined by the " undergearing " desired to obtain maximum acceleration.

CHAPTER TWENTY

The Third Decade

THE end of the third decade of motor racing history coincided with the production of the world's fastest road-racing cars, but the margin of superiority held by the 1939 3-litre 500 h.p. designs over the 1937 650 h.p. types was a small one. It is legitimate to ask why, in fact, the former had any superiority at all, and it may help to put the problem in perspective if some of the relative data is tabulated :

	1937 Mercedes-Benz W125	1939 Type W163
Average Lap Speed Index (1906 Renault = 100) ..	163.5	165
Inferred Maximum Speed (square law)	193 m.p.h.	196 m.p.h.
H.P. per sq. ft.	51.5	39
and Inferred Maximum Speed (cube law)	204 m.p.h.	185 m.p.h.
Best Timed Speed.	193 m.p.h. (Spa)	195 m.p.h. (Rheims)
Theoretical Average Index based on h.p. per sq. ft. (Sixth root law)	163.5	160

It is immediately apparent that the average speed index moves almost exactly with timed maximum speeds on the road (at Spa and at Rheims respectively), but the W125 car failed to reach its theoretical maximum by 5.5 per cent, whereas the Type W163 exceeded the theoretical speed by a like percentage. The deficiency on the larger car is easily explicable for within the limits of the four gears available the ratios were naturally chosen to give the best overall speed, and although peak r.p.m. coincided with 200 m.p.h. on the highest gear and the biggest tyre, on the lowest gear ratios (using the smallest wheels) only 122 m.p.h. was attained. A very large number of intermediate proportions between crankshaft and road speed could be fitted but even on a very fast circuit such as at Berne the best circuit speed of 107 m.p.h. was secured with a gear limiting the maximum to 160 m.p.h.

These changes do not affect the fundamental proposition that average speeds on a circuit vary as the sixth root of the h.p. per sq. ft., but with the W163 both maximum and averages substantially exceeded expectations based on this ruling. On this car five forward speeds eliminated the need for under gearing in the interests of the best possible acceleration, and it is instructive here to compare speeds available at 7,800 r.p.m. on the Type W163 with the W125 running at 5,800 r.p.m. :

RELATIVE ROAD SPEEDS AT PEAK R.P.M.
MERCEDES-BENZ W125 AND WI63

	I	II	III	IV	V
W125 (m.p.h.).	78	123	142	178	—
W163 (m.p.h.).	61	109	135	158	197

From the foregoing, it is patent that the W125 was normally undergeared, but equally on the above ratios the W163 was overgeared in that the b.h.p. per sq. ft. of frontal area should have been insufficient to reach peak r.p.m. in fifth speed. The two cars had identical frontal area, and on the cube law the Type W163 needed 47 h.p. per sq. ft. or 590 h.p. gross to reach 195 m.p.h. This was 100 b.h.p. or 22 per cent more power than the engine actually produced, and we are forced to conclude that the shape of the body on the W163 must have had a useful effect in reducing drag. A reduction in drag coefficient of about 15 per cent is needed to account for the timed speed in relation to power available, and although it has been taken as an axiom that changes in body form do not sensibly affect the drag coefficient this design seems the exception that tests the rule. If one studies the cars in detail the figures fall within the realm of reasonable probability.

An examination of the scale drawings shows, although both cars had a frontal area of 12.5 sq. ft., the body on the 1937 model was comparatively high and narrow with projecting front wishbones and rear suspension elements, and a high-mounted radiator core with a deep oval orifice having separate air entries for oil cooling. The front aspect of the 1939 model shows almost complete enclosure of the chassis parts and very low mounted radiator core with a wide intake.

Some of these features are even more vividly disclosed in the side elevations reproduced in this chapter. The comparatively blunt nose of the 1937 model will be seen at once, and the radiator core on the 1939 car was placed much farther forward so that the air exit behind it was correspondingly much freer. The importance of this particular feature is proved by the fact that advancing the core by 3½ in. as compared with the 3-litre W154 made it possible to reduce the depth of the element by one-third, from 6 in. to 4 in.

The cooling drag on the W163 has been estimated at 8 per cent and this is probably much lower than anything achieved on the W125, so that taking all the factors into consideration a reduction in drag coefficient from a Cw factor of, say, 0.65 to 0.55 is not unreasonable. Both of these figures may, indeed, seem unreasonably high, bearing in mind that a 1939 touring saloon car also had a Cw figure of 0.55, but for many reasons major reductions in drag by streamlining have not proved a practical operation on road-racing cars, although great progress was made in this direction on record-breaking cars between 1930 and 1939.

In the pre-Grand Prix era some designers, notably Gobron Brillie and Mors, went to some trouble to reduce wind resistance by using bonnets tapering to a knife-edge at the front, the radiator being separately mounted ahead of the front axle and thus in the correct position to receive air at maximum pressure and to discharge it with no loss due to back pressure. Mors (and the associated Turcat Méry) also pioneered the long tail body for road racing in the cars they ran in 1904.

These seeds fell on stony ground, but in 1914 Henri addressed himself to another aspect of the problem and produced a long cylindrical tail for the 4½-litre Peugeot cars. There is evidence that this was useful on high-speed tracks such as Indianapolis.

The next step was taken by those two highly original engineers, Bugatti and Voisin, both of whom sponsored cars of quite unorthodox shape which ran in the 1923 Grand Prix at Tours. Calculations based on speed and maximum power con-firmed ocular evidence provided by dusty roads that these shapes were efficacious in

PLATE XXIII

THE DEVELOPMENT OF THE ROAD RACING BODY FORM 1920-39

Between 1906 and 1914. and especially between 1912 and 1914. the outward form of the Grand Prlx car underwent a radical revision. Some side elevations shown in Volume 1 indlcate that there was a marked drop in seat height derived from underslinging the rear springs, by cranking the frame over the rear axle and, in some cases, over the front axle as well. The type of body used. however, changed but little, and was simply of two bucket seats with shallow side-members, a transverse fuel tank and one or more spare wheels.

In 1914 both Peugeot and Fiat broke away from this convention and produced cars with long tails, the former make having two spare wheels mounted longitudinally in the tapering cigar-shaped form.

From this point onwards the changes in design, shape, and frontal area have been more subtle and these drawings have been especially prepared to a uniform scale so that successive stages can be readily followed.

TWO-SEATER DESIGN. – Until 1925 international regulations insisted on a driver and mechanic as the crew of the Grand Prix car and for this reason two-seater bodies were required.

The larger car shown in these two drawings – the 1920-1 Ballot – had a 3-litre, eight-cylinder, engine developing 107 b.h.p., and a feature of the body design was the marked offset between the driver's and mechanic's seat. Pronounced upsweep to the cowl gave good protection to the crew and the frontal area was approximately 12 sq. ft.

The Delage was designed three years after the Ballot for the 1922-5 regulations, and had a 2-litre V.12 engine. which in the 1925 supercharged version, developed 190 b.h.p. Staggered seating was continued, but both members of the crew placed much lower so that although there was little change in radiator height the frontal area was reduced to 11 sq. ft. This figure includes the cowling over the front axle which may well have reduced windage loss compared with the exposed front axle parts of the earlier car, despite the lesser frontal area of the latter.

A particularly interesting point brought out in these drawings is that comparatively small changes dimensionally have a big effect on the general appearance of the vehicle, this point being further emphasised by the study below of the differences between 2-litre and 1½-litre model Delage cars.

THE OFFSET SINGLE-SEATER. – From 1925 onwards only the driver had to be accommodated in the racing car and this led to the construction of offset single-seater chassis and bodies by Talbot and Delage for the 1926-7 1½-litre Grand Prix formula.

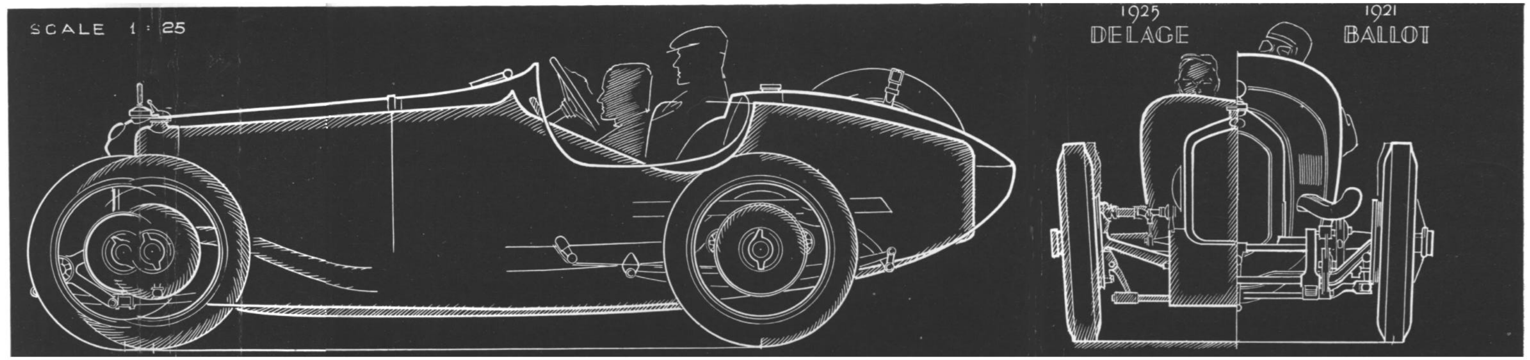
In the Delage design the crown wheel and pinion was offset approximately 4 in., to the left-hand side of the car, and this made it possible to mount the single seat to the right so as to avoid the need for giving clearance for a propeller shaft beneath it. The result, in the outline shown shaded in this drawing, was a remarkably low overall height with a frontal area of only 9½ sq. ft., features which appreciably improved both the performance and the stability of the car. The low mounted radiator on the 1927 model was placed ahead of the front axle so as to avoid fouling between the bottom tank and the axle beam.

CENTRAL DRIVING POSITION. – The success of the the 1932 P.3 Alfa Romeo Monoposto popularised a central driving position with a seat highly mounted above the propeller shaft. This gave a greater frontal area than the extremely low offset single-seaters of the 1926/7 period, but offered the driver an excellent and symmetrical view of the road.

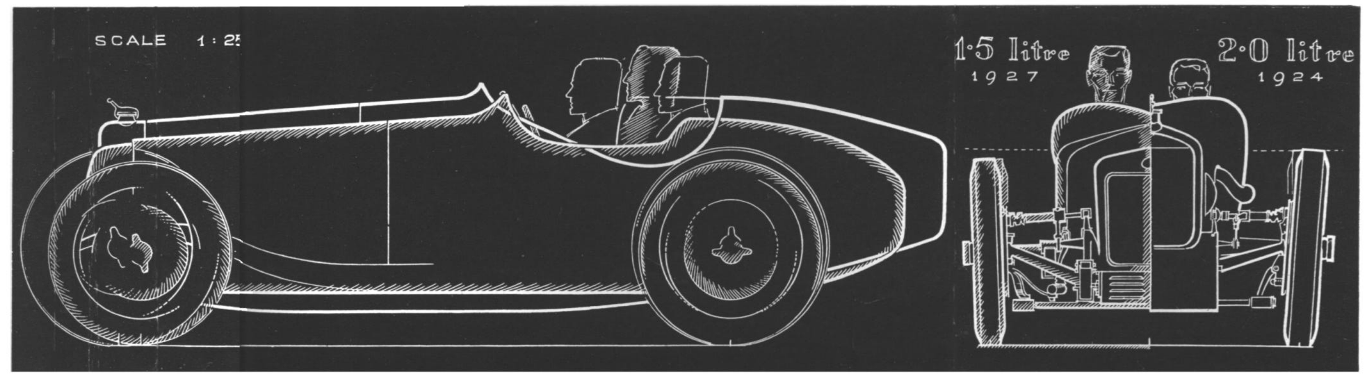
This theme was continued by Mercedes-Benz with their 1934-5 Type W.25 A and B cars, but as these models had independent suspension to the rear wheels no provision had to be made for the rise and fall of the propeller shaft. Additionally the latter was offset downwards by using an indirect drive on all ratios. An effort was made to reduce wind resistance by providing deep fairing behind the driver's head, but the nose of the car remained blunt with a vertical rectangular air opening to the cowl.

By successive development through the 1936-8 period the V.12 cars in 1939 had a long tapering nose with a low set oval air intake. The height of the driving seat was considerably reduced by offsetting the propeller shaft to the left and driving the rear wheels through two indirect trains of gears giving an offset downwards of over 11 in. The difference in frontal area was as between 11.8 sq. ft. for the 1934 model and 12½ sq. ft. for the 1939, but the latter figure included an almost complete enclosure of all the chassis parts. It can be proved that the general shape and refinement of the 1939 car resulted in a useful reduction in drag, but comparing this model with the 1921 Ballot, one can see at a glance the immensely greater proportion of the frontal area represented by wheels and tyres, which are obviously extremely bad shapes from the viewpoint of wind resistance.

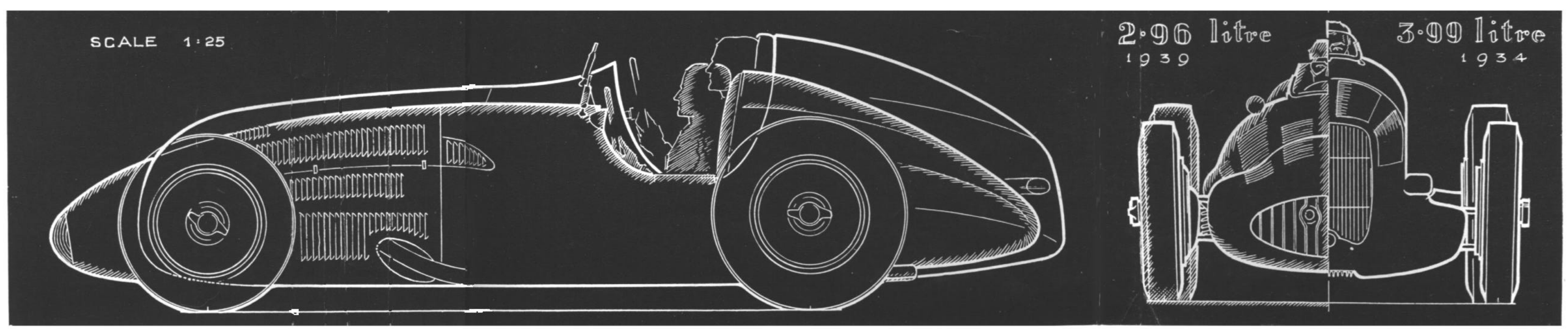
Hence with the greatest possible refinement in shape the wind resistance coefficient of the fastest 1939 Grand Prix car was only some 15 per cent less than the 1906 winner, although as frontal area had been reduced by over one-third the overall power needed at a given speed was reduced by over 40 per cent.



The 1920–1 3-litre Ballot and 1925 2-litre Delage



The 1925 2-litre Delage and the 1926-7 1.5-litre Delage



The 1934–5 3.99-litre Mercedes-Benz and the 1939 3-litre Mercedes-Benz

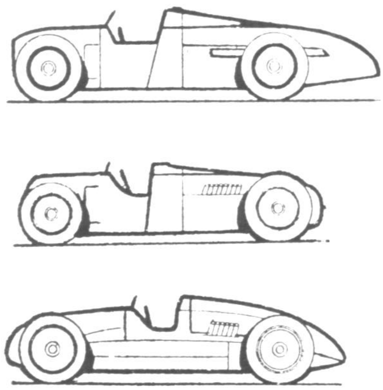
reducing drag, but once again development along these lines was not continued and designers concentrated on obtaining minimum frontal area. This theme was continued throughout the third decade of Grand Prix racing, but concurrently both Auto Union and Mercedes-Benz amassed a great deal of data on really low drag body forms which they used for record breaking. For example, in 1935 a new body was developed in the wind tunnel of the Dresden Technical High School for an Auto Union record car. It was based on the road-racing model, but the cockpit was completely enclosed and fairings were placed behind the front wheels, the rear wheels being wholly encased. The suspension units were also covered up and although frontal area was increased by 25 per cent the Cw figure was reduced by 35.5 per cent, the overall drag thus falling by 20 per cent. On the road this car reached 199 m.p.h.

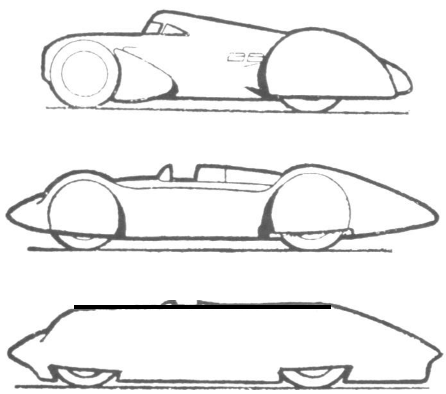
Two years later, in 1937, Auto Union built a fully enveloping body to be used on the A.V.U.S. track and for record-breaking purposes. In this design the frontal area was 45 per cent greater than the corresponding Grand Prix road car but, as the drag coefficient was reduced by 61 per cent, the overall wind resistance fell by 44 per cent. The car achieved a speed of 255 m.p.h. and did a standing lap of the twelve-mile A.V.U.S. circuit at 171.6 m.p.h., which compares with 165 m.p.h. obtained with the G.P. model. Mercedes-Benz also designed bodies of this type, and on the A.V.U.S. track lapped at 165 m.p.h. whereas as with the same type of engine fitted in the normal Grand Prix car the lap speed was only 159.5 m.p.h.

In 1938 Auto Union went further by designing a fully enveloping streamlined car for the French G.P. held on the very fast Rheims road circuit, but it proved more difficult to drive than the normal types and development work was suspended. During this year, also, Mercedes-Benz built a car with fairings over the front and rear wheels which they planned for use at Tripoli in 1939. The car never ran, as the race in that year was confined to 1½-litre cars, but a modification of the layout was used for standing-start records in the 3-litre class in February 1939. On the same occasion the 3-litre road-racing chassis attained 248 m.p.h. with a fully enclosed body.

Despite these experiments the gains derived from streamlining road-racing cars have been consistently outweighed by the disadvantages thereof. In particular, a reduction in drag brings the centre of wind pressure considerably forward of the centre of oscillation, the car becomes aerodynamically unstable and at high speeds particularly sensitive to cross-winds, such as may impinge upon it suddenly as, for example, when running out of a line of trees into open country. Moreover, nothing less than total enclosure of the wheels and suspension elements (which form half the frontal area) has any large effect on drag, for these parts are organically quite unrelated to the hull and quite impossible to streamline individually. The body in itself can be so shaped that it only offers 5 per cent of the entire resistance and changes in the form have, therefore, a quite negligible effect on the total drag.

Undoubtedly the worst handicap of the streamlined body is the increased all up weight, and, for example, the fully enclosed A.V.U.S. Auto Union car was 11 per cent heavier than the Grand Prix type. Both cars were run in record-breaking attempts over standing kilometres and standing miles and over a kilometre (i.e. 1,095 yds.) the Grand Prix car was the faster by 0.02 sec. Over the mile (1,760 yds.) the fully Stream-lined type was the quicker by 0.81 sec. They would have dead-heated over a standing 1,400 yds.





FIVE YEAR DEVELOPMENT – These 1 : 100 scale drawings show the development of Auto Union cars for road racing (left) and record breaking (right). Reading downwards, the left-hand drawings show the 1934 long-tailed car and immediately below it is the 1936 type with longer wheelbase, greater tank capacity, but shorter tail. Bottom left is the 1938/9, 3-litre car with the driver mounted farther back on the frame as a consequence of a shorter engine and side tanks in place of the previous centrally mounted fuel reservoir. In the right-hand column can be seen the record-breaking models of 1935. 1936 and early 1938 with maxima of 199 m.p.h., 252.5 m.p.h. and 270 m.p.h. respectively.

To sum up, by adopting fully streamlined bodies the maximum speed of the 1939 3-litre cars could have been raised by about 50 m.p.h., but acceleration would have been impaired and braking very seriously affected, not only by the greater weight, but also by reason of the lesser retardation brought about by wind resistance.

This brief resume of the facts may serve to explain why an apparently obvious way of increasing speed made little progress before 1939, but it must be read in conjunction with the abundant engine power available under the regulations which governed racing during 1934-9.

At the beginning of the decade racing cars were powered with engines of approximately 3 litres capacity developing 200 b.h.p. Exact figures of the weight of such engines are lacking, but 300 lb. may be considered typical. Progress during the lifetime of the 750 kg. formula was as follows :

	Engine Capacity	*Weight*	*Output*	*Weight per B.H.P.*	*Weight per litre*
1934 Italian Straight-eight . .	2.9 litres	300 lb.	210 b.h.p.	1.43 lb.	103 lb.
1934 Mercedes-Benz . .	3.36 ,,	449 ,,	345 ,,	1.27 ,,	134 ,,
1934 Auto Union	4.36 ,,	540 ,,	295 ,,	1.83 ,,	124 ,,
1935 Mercedes-Benz	3.99 ,,	456 ,,	430 ,,	1.06 ,,	115 ,,
1935 Auto Union	4.95 ,,	540 ,,	340 ,,	1.58 ,,	108 ,,
1936 Mercedes-Benz	4.74 ,,	465 ,,	494 ,,	0.94 ,,	98 ,,
1936 Auto Union	6.01 ,,	540 ,,	520 ,,	1.08 ,,	90 ,,
1937 Mercedes-Benz	5.66 ,,	490 ,,	646 ,,	0.71 ,,	81.5 ,,
1937 Auto Union	6.00 ,,	540 ,,	520 ,,	1.08 ,,	90 ,,

Weight per litre fell steadily with increase in swept volume, a logical development since, with the exception of the 1937 Mercedes-Benz, the physical dimensions of the racing engines built during this period remained unchanged. Reciprocating weights also remained virtually constant despite an increase in cylinder bore size from 68 mm. to 75 mm. by Auto Union. In the Mercedes-Benz engines the diameters of the cylinder

bores were successively raised from 78 mm. to 94 mm. On both cars r.p.m. remained almost constant, but the overall inertia forces were considerably increased by rising piston speeds.

Gas loadings also rose as boost pressures and compression ratios were both increased, but in the higher speed ranges these forces and those set up by inertia were counter balancing and this, coupled with the use of roller bearings, explains why reliable running was achieved.

Whereas, however, the Auto Union engineers claim that a set of plain crankshaft bearings and roller big ends could be used throughout a season, the Mercedes-Benz power units were more highly stressed and the components thereof were usually changed after two, or at the most three, races. The general dimensional differences between the two engines used between 1934 and 1937 under the 750 kg. formula are given in a detail table.

	Auto Union			Mercedes-Benz		
	1934 A	1935 B	1936 C	1934 25A	1935 25B	1937 125
Bore (mm.)	68	72.5	75	78	82	94
Stroke (mm.)	75	75	85	88	94.5	102
S/B Ratio	1.1	1.035	1.13	1.13	1.15	1.08
Cylinder Capacity (c.c.)	272.5	310	375	407	497	710
No. of Cylinders	16	16	16	8	8	8
Angle of V	45	45	45	in line	in line	in line
Swept Volume (litres)	4.36	4.95	6.01	3.36	3.99	5.66
Piston Area (sq. in.)	90	102.5	109.5	59	65	86
Connecting Rod Centres (mm.)	164	164	164	161	161	161
Distance between Cylinder Centres (mm.)	86	86	86	95	95	104
Main Bearing Diameter (mm.)	62	62	70	63	63	66
Crankpin Diameter (mm.)	58	58	68	55	55	63
Manifold Pressure (Ata.)	1.57	1.73	1.93	1.66	1.66	1.86
Compression Ratio	7.1	8.95:1	9.2:1	6.0	6.0	6.0
Maximum b.h.p.	295	375	520	302	430	646
At r.p.m.	4,500	4,800	5,000	5,800	5,800	5,800
Maximum b.m.e.p.	231	248	268	210	262	310
At r.p.m.	2,700	3,000	2,500	4,000	4,000	3,300
B.m.e.p. at Max. h.p.	200	210	230	203	242	256
B.H.P. per sq. in of Piston Area	3.28	3.66	4.75	5.15	6.6	7.52
At ft./min. Piston Speed	2,220	2,270	2,900	3,360	3,600	3,900

The immense gain in overall engine performance between 1934 and 1937 has been treated in detail in preceding chapters. It was derived almost entirely by greater engine size and higher mean effective pressures and whereas in 1934 a typical racing engine of the Italian school had 46 sq. in. of piston area, in 1937 Mercedes-Benz engines used 86 sq. in., an increase of 87 per cent, and Auto Union 109.5 sq. in., an increase of 138 per cent.

Making a comparison of b.m.e.p. figures the typical 1934 car developed 185 lb. per sq. in. at the peak of the power curve, but the Auto Union C Type improved upon this by 44 per cent and the Mercedes-Benz Type 125 by 67 per cent and such large gains were out of all proportion to any change in absolute induction pressure which was raised by not more than 15 per cent during the period under review. Are we therefore asked to agree the apparently impossible proposition that the breathing of the best 1937 engine was some 50 per cent better than the 1934 type at equivalent boost pressures ? That is too simple an analysis, for the gain in power was compounded by (a) improved breathing (although not to the extent just indicated), (b) higher compression ratio and better combustion efficiency, (c) increased weight of charge, and (d) considerably higher mechanical efficiency.

The gain under heading (a) was probably limited to between 10 and 15 per cent and of the two factors (b) and (c) the latter was probably much the more important, particularly on the Type 125 Mercedes-Benz fitted with the auxiliary jet giving a great increase in fuel flow on full throttle. Results have been quoted showing that this in itself raised the power output by 14 per cent, chiefly owing to the reduction in mixture temperature and corresponding rise in charge weight, it being remembered that power output of an engine is strictly proportional to the weight of air burnt in unit time.

Exact figures of the relative mechanical efficiencies of racing car engines are hard to find but Auto Union learned that the full roller-bearing type of engine showed considerable improvement compared with a design using plain main bearings and roller-bearing big ends, so it is fair to infer that the difference would be even greater if the comparison were made between an all roller bearing unit and an all plain type.

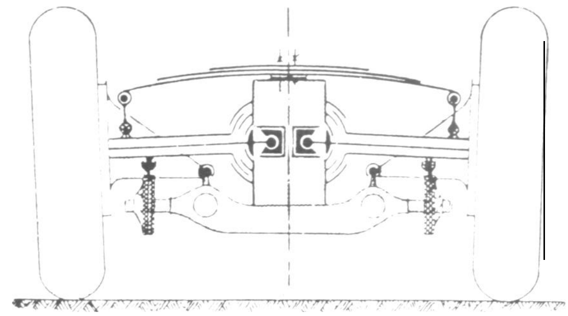
It has been suggested by Mercedes-Benz engineers that the former would show a 10 per cent gain in power over the latter and if this figure be accepted all but 6 per cent of the 50 per cent difference above mentioned has been accounted for. This relatively small fraction can reasonably be ascribed to changes in compression ratio, improved plug position and similar details. Over and above these specific gains the German cars were, of course, outstanding in that the large efficiency engines produced by them were light and outstandingly reliable.

From 1934 the Italians fell farther and farther behind in power output ; in fact, from 1936 onwards they were outclassed by between 100 and 200 b.h.p. This was a reflex of the vastly greater engineering effort in terms of cash and man-hours which went into the production of the German cars and, confining our attention to them for the moment, we observe that similar ends were secured by utterly opposite means.

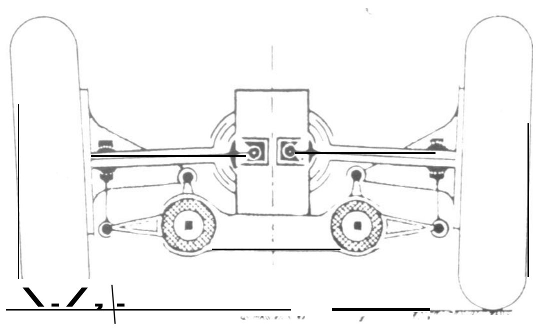
The dimensional differences between Mercedes-Benz and Auto Union engines have been tabulated, but the constructional variations are even more striking in that both the main forms and detail layouts had nothing in common :-

AUTO UNION SUSPENSION SYSTEMS 1934-8

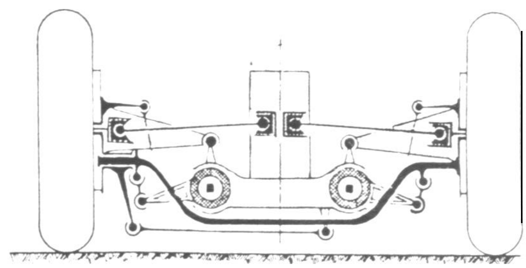
(I) In 1934 the A Type Auto Union had a transverse leaf rear spring mounted very high at the back of the car. In conjunction with the swing axle this produced an exceedingly high rear roll centre leading to great stiffness at the back of the car and consequent natural over-steeritg qualities.



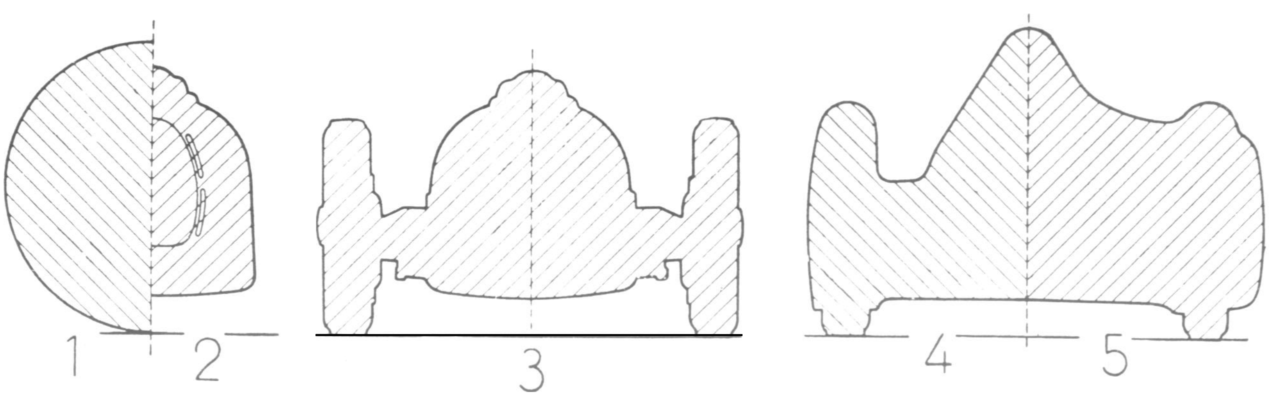
(2) In 1935 the system was modified to embrace torsion bars in place of the previous leaf spring. This resulted in a considerable saving in weight and a reduction in spring stiffness to 230 lb. per in.; the rear end geometry was unchanged.



(3) At the cost of considerable mechanical complication the 1938-9 3-litre cars were equipped with de Dion type rear axle. This drawing shows the change to four universal joints and the layout of the transverse de Dion tube with Panhard rod to give a sideways location. It will be noted that the de Dion tube can oscillate in a bearing adjacent to the left-hand hub. By this means the roll centre at the rear is considerably lowered and in conjunction with a softening in the suspension of 1 in. per 175 lb., over-steering tendency of previous models was eliminated.



AUTO UNION BODY FORMS 1935-7



The total frontal area of the 1936-7 Auto Union car shown in Figure 3 amounted to 10.8 sq. ft., equivalent to the circle shown in Figure I. Figure 2 shows the bare hull of the G.P. car with a frontal area of 5.96 sq. ft. This hull had a drag coefficient factor (Cw) of only 0.057 which was under 10 per cent of the figure for the complete car which had a drag coefficient figure Cw 0.61. The overall drag of the bare hull was, therefore, only 5 per cent of the total wind resistance of the complete Grand Prix car.

Figures 4 and 5 show the record-breaking cars built in 1935 and 1938 with frontal areas 25 per cent and 45 per cent greater than the Grand Prix car but with overall drag reduced by 20 per cent and 44 per cent respectively by reason of a reduction in wind resistance coefficient Cw to 0.393 and 0.200 in each case.

CONSTRUCTIONAL DIFFERENCES OF 750 Kg. FORMULA AUTO UNION AND MERCEDES-BENZ ENGINES

	Auto Union	Mercedes-Benz
Number of Cylinders	16	8
Arrangement of Cylinders	V	In line
Cylinder Construction	Detachable wet liners	Steel forgings
Cylinder Type	In one with crankcase	Detachable blocks
Water Jackets	In one with crankcase	Welded steel sheet
Cylinder Head Type	Detachable	Integral with bores
Cylinder Head Material	Light alloy	Steel
Number of Valves	2	4
Valve Angle	90 degrees	60 degrees
Number of Camshafts	1	2
Main Bearings	Lead bronze	Roller
Big Ends	Roller	Roller
Connecting Rod	One-piece	Split big end
Crankshaft , ...	Hirth built-up	One-piece

Overriding these divergences in engine design the Mercedes-Benz cars had normal front engine position, but Auto Union used a rear engine mounting.

The Auto Union engine was the heavier of the two, and as there was very little difference in the weight of the cars, it may be fairly claimed that the rear end design resulted in some weight saving. There can be no question that it produced a lower built car and less frontal area. There can, equally, be no question that in its 750 kg. formula manifestation the rear-engined Auto Union was a considerably more difficult car to handle than the Mercedes-Benz, particularly in 1937 after the latter had adopted the de Dion rear axle.

Some figures have been cited in Chapter 18 bearing upon this point and interesting confirmation has been received from Hans Stuck who was the original leading driver for Auto Union. He resigned from this team after the Italian Grand Prix in 1937 and in the subsequent Masaryk Grand Prix at Brno attended as a spectator. When the Mercedes-Benz team had ended their official practice he was invited to try one of the W125 cars on which the fastest practice had been put up by Lang at 93.8 m.p.h. After only one lap to gain experience of the new car Stuck did a circuit at an average of 94.2 m.p.h. without, as he has explained, taking more risks than were normal in his previous experience with Auto Unions. He returned to the latter team during 1938 and although he confirms that the handling of the smaller cars with de Dion rear axles was an improvement over the previous types he remains convinced that although there may be engineering advantages to be derived from a rear engine location stability is best obtained with the normal forward mounting.

The technical aspects of independent front and rear suspension have been mentioned in Chapter 27, and it is only necessary to recapitulate briefly that during the three racing seasons 1934-6 wheel travel was limited and, in consequence, the full advantages of independent front suspension were not realised.

There is no evidence that independent suspension systems were in themselves an aid to average speed, although paradoxically there is definite proof that improvements in all-round roadworthiness on cars with rigid axles made a marked difference to lap speeds in the first two years of the third decade. This notwithstanding, no car with a rigid front axle won a major race after July, 1935, and no car with a torque tainted rear axle was successful in major events after August, 1935.

The most sensible appreciation of the value of the early types of independent front suspension would be to say that they made possible greater circuit speed derived from very big increases in engine power, and it is probable that the biggest contribution to this end was derived from independently springing the rear wheels rather than by using independent front suspension.

An exact assessment of the merit of these new designs is obscured by the changed handling characteristics. The combination of large surplus engine power with swing axle geometry made the German cars violent over-steerers, but, at the same time, the elimination of torque effect made a profound difference to the possible acceleration. Some measure of the progress which was made can be deduced from the standing kilometre speeds put up by formula racing cars as follows :

Maserati 2.9-Litre :	88.87 m.p.h., 23rd March, 1934. A.I.231.
Auto Union (B Type) :	101.56 m.p.h., 20th October, 1934. A.I.254.
Auto Union (C Type) :	117.3 m.p.h., 26th October, 1937. A.I.254.

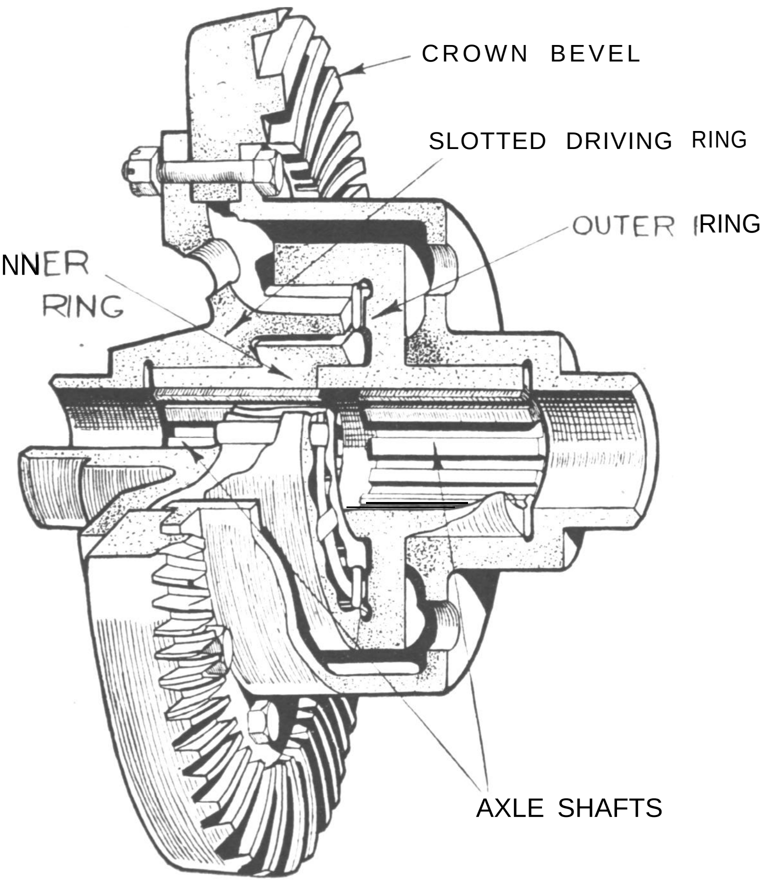
By 1936, however, it was becoming increasingly evident that the swing axle system presented serious problems of road holding. These were caused by variations of toe-in as radius arm controlled wheels rose and fell and, more important, by gyroscopic reactions from heavy, large section, tyres.

The revival of the de Dion type of axle by Mercedes-Benz in 1937 may, therefore, be considered as much a milestone in design as the adoption of all independent suspension by Auto Union and Mercedes-Benz three years previously.

The introduction of the limited slip differential was a great aid to acceleration, for even with one rear wheel clear of the ground a useful propulsive effort was maintained. **A** drawing shows the essential elements of the device and two curves show the essential differences in performance between a rear axle equipped with this device and the alternatives of solid axle or the normal gear-type differential.

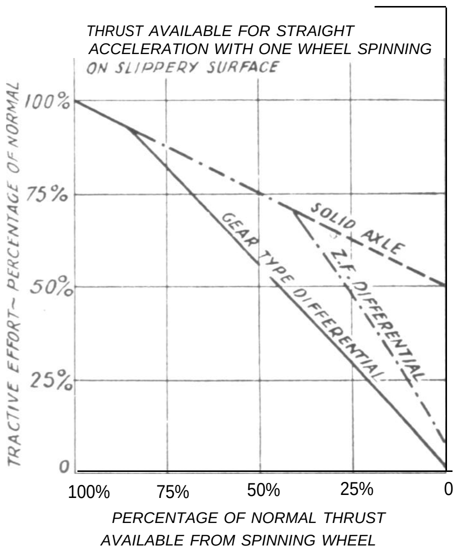
Both when cornering, and when the power available is greater than the adhesion factor, traction is considerably improved when the Z.F. differential is used. The reason for this in brief is that the Z.F. mechanism is inherently inefficient and the disproportion between power input and power output rises with change in speed between the inner and outer wheel. On very sharp corners 50 per cent of the input power may be absorbed in the friction set up by the Z.F. mechanism and this in itself makes it more difficult to spin the wheels, a particularly valuable feature on the 1937 cars which had so high a power : weight ratio that excessive wheelspin and loss of control was

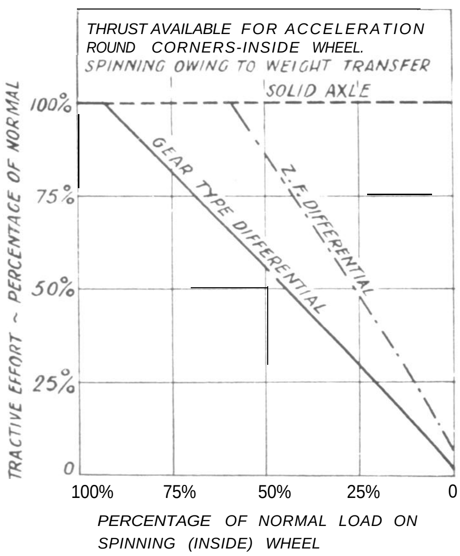
only avoided by the most delicate use of the throttle. A further drawing shows the principle of the Z.F. differential which was used by both Auto Union and Mercedes-Benz.



Mercedes Z.F. differential.

COMPARATIVE GRAPHS RELATING TO Z.F. DIFFERENTIALS





Apart from major changes in design the third decade of motor racing was notable for its useful advances in metallurgy and fabrication. In particular the art of welding thin wall steel tubes into frame and body structures made it possible to provide the very stiff frames called for by independent front suspension systems without running over the limit of weight imposed by regulations. The latter made it necessary for every detail of the car to be executed with the weight factor in mind and the reliability of the 750 kg. cars is, therefore, all the more remarkable. In the 1937 season, for example, Auto Union entered 33 cars for 10 races, and had only 3 retirements for mechanical reasons. The Mercedes-Benz record was 38 cars running in 10 events with 5 withdrawals caused by mechanical failure.

The capacity limit regulations introduced in 1938 and valid for the succeeding year destroyed these fine records. In these two years 16 Auto Unions broke down out of 45 entered in 13 races, and Mercedes-Benz retirements due to mechanical trouble were 16 cars out of 48 entries in 16 races.

As we have seen the German 3-litre engines both had twelve cylinders arranged in a V, but both continued with the same basic design as in previous years, so that the marked differences in engine construction continued. Dimensionally the engines compared thus :

	Auto Union D Type	*Mercedes-Benz Ml63*
Bore (mm.)	65	67
Stroke (mm.)	15	70
S/B Ratio	1.15	1.04
Cylinder Capacity (c.c.)	249	249
No. of Cylinders	12	12
Angle of V	60	60
Swept Volume (litres)	2.99	2.99
Piston Area (sq. in.)	61.5	65.5
Connecting Rod Centres (mm.)	168	148
Distance between Cylinder Centres (mm.)	86	93
Main Bearing diameter (mm.)	70	60
Crankpin diameter (mm.)	66	54
Maximum b.h.p.	485	483
At r.p.m.	7,000	7,800
Maximum b.m.e.p.	345	285
At r.p.m.	4,000	4,000
B.m.e.p. at maximum h-p.	305	270
B.h.p. per sq. in. of Piston Area at ft./min. Piston Speed	7.9 at 3,460	7.4 at 3,600

If these figures be compared with those obtained on the engines built under the 750 kg. formula it becomes apparent that piston speeds changed but little but absolute manifold pressure was raised by some 55 per cent to give an increase in b.m.e.p. of 10 per cent. This apparently poor return was undoubtedly due to the increase of 35 per cent in the peak r.p.m. for obviously at nearly 8,000 r.p.m. the problem of maintaining satisfactory breathing through the valves was considerably greater than at the more modest figure of 5,800 r.p.m.

This was shown with the first 3-litre engines using single-stage blowing, which showed a marked deterioration in both power per sq. in. of piston area and b.m.e.p. compared with the larger, slower turning, engines used in the previous year. Thus higher boost pressures were required to restore the situation and as mentioned in previous chapters they hinged upon the use of some form of compressor with internal com,pression, or the use of Roots displacers mounted in series so as to limit the pressure rise across each stage.

As explained in Chapter 21 the characteristics of the centrifugal type of compressor make it completely unsuitable for road racing and all Vane type pumps embody some out-of-balance mechanism which limits their maximum reliable running speed. Although the Vane type has some superiority in displacement per revolution compared with an equivalently sized Roots blower, a mechanism required to run at say two-thirds engine speed must obviously be far more bulky than a Roots type running four times faster, i.e. at 2.5 times engine speed.

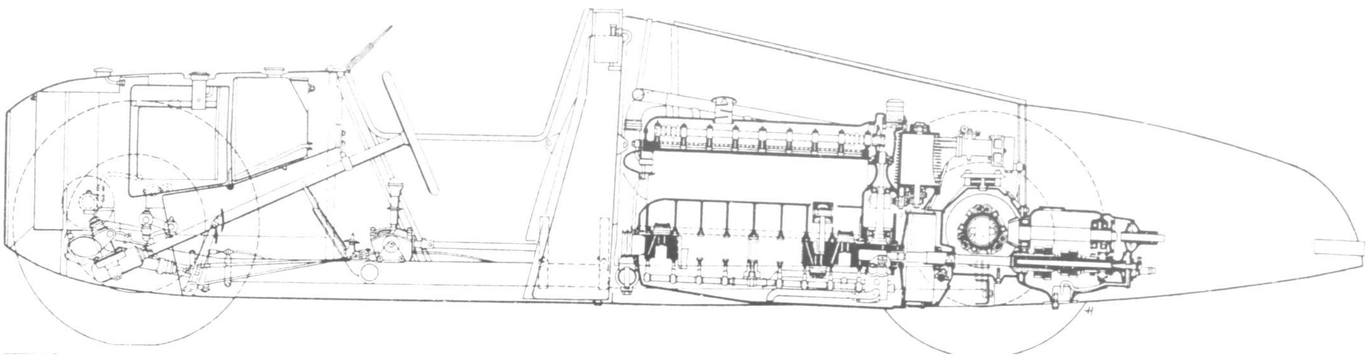
On a 3-litre engine, requiring a total air flow of over 30,000 litres a minute, the size of any Vane type compressor running at less than a multiple of engine speed would indeed be prohibitive and for this reason in 1939 both Mercedes-Benz, who had consistently used Roots blowers for some 15 years, and the Auto Union Group, whose motor-cycle component had had much successful experience with Vane type compressors, decided to use the Roots type pumping through two stages.

The entire volume of a blower having no internal compression has to be delivered against the existing contra pressure. Thus if, for example, in one revolution of the blower 2 litres of mixture is delivered against a 25 lb. contra pressure the work done may be assessed as 2 litres by 25 lb. or 50 work units. But if a second blower of 1.4 litres capacity be interposed between the first stage and the engine the sequence of events will be as follows. The first stage will deliver two litres against a back pressure of 9½ lb. per sq. in. absorbing 19 work units in the process. By virtue of the compression of the charge the second stage will receive 1.4 litres compressed to 9½ lb. above the atmosphere and will feed them into the engine against 25 lb. back pressure, the pressure difference thus being 15½ lb. The product of volume by pressure (1.4 x 15.5) may be considered as 22 work units making the sum for both stages 41 work units and lowering the power required to compress 2 litres up to 25 lb. by 18 per cent.

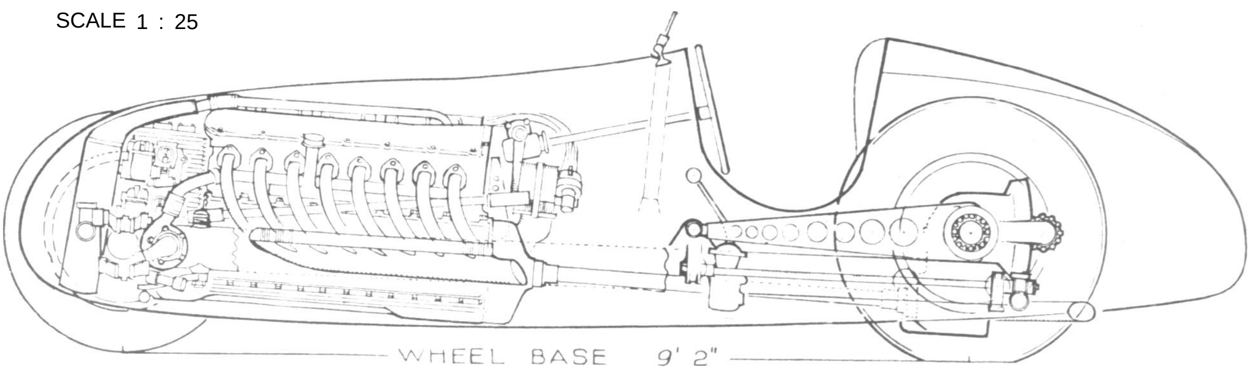
On the 1938 3-litre Mercedes-Benz the single-stage blower drive absorbed some 150 b.h.p. and it will be seen that on the above theoretical example a saving of some 30 b.h.p. might be possible by using two stages. The issue was, of course, more complicated because in addition to adding a stage of boost the absolute manifold pressure was also raised, but as shown in some curves there was a substantial net gain following from the change in the blower system.

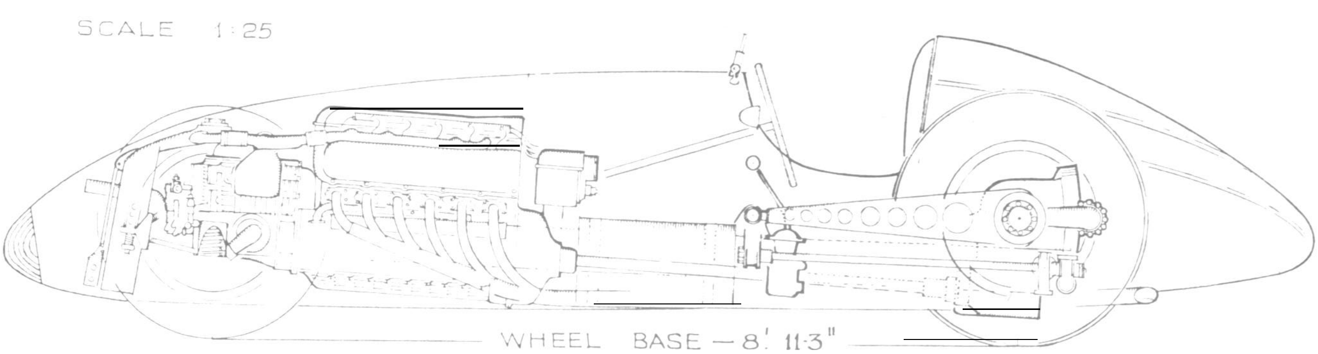
It should also be put on record that Mercedes-Benz designed a direct fuel injection system on their twelve-cylinder engines and carried out trials on two single cylinder test units. As one might expect, this reversion to the obsolete practice of passing air only through the superchargers gave distinctly disappointing results. On a 400 c.c. test cylinder with fuel injection 146.3 h.p. per litre was realised with 3,500 f.p.m. piston speed; on a 187 c.c. test cylinder 166.5 h.p. per litre was realised at 2,600 f.p.m. piston speed with normal carburation.

SIDE ELEVATION OF RACING CARS 1934-9



SCALE 1 : 25





Top: 1934 Auto Union A Type
Centre: 1937 Mercedes-Benz Type 125
Bottom: 1939 Mercedes-Benz Type 163

As under the 750 kg. formula, so under the 3-litre restriction, Auto Union placed the engine behind the driver and Mercedes-Benz in the orthodox position, but both cars had wholly different handling qualities to their predecessors. As between 1934 and 1939 the spring rate on the Mercedes-Benz was decreased by 40 per cent at the front and 66 per cent at the rear. On the Auto Unions the rate of suspension between these years was lowered by 50 per cent at the front and 40 per cent at the rear, and in 1939 both cars had de Dion type rear axles.

A very full account of the suspension characteristics of the two makes is given by Cameron Earl in his B.I.O.S. Report No. 1755 (" An Investigation into the Development of German Grand Prix Racing Cars between 1934 and 1939 "), which is one of the few works which should be considered as obligatory reading by the serious student of racing car design.

The changes in the Auto Union rear-axle layout are shown in some drawings. The roll-centre on the swing axle cars can be fixed by drawing a line from the centre of the tyre tread through the centre point of the spherical bearings, but on the de Dion axle the roll-centre is about the articulations of the transverse Panhard rod. Thus, on the earlier cars the value of the roll-couple at the rear was far higher than at the front, but on the 1938-9 models this no longer obtained and both Auto Union and Mercedes-Benz became fundamentally understeering vehicles. There was so much power available on the rear wheels, however, that wheelspin could, despite the Z.F. differential, be induced at will, and by this means the attitude of the car on a curve could be controlled accurately by the skill of the driver.

In the opening pages of Volume I the author explained how Grand Prix racing had been started, largely as a political manceuvre to demonstrate the superiority of French cars and how, in the last five years preceding World War II, it became again primarily a political instrument, but at this time to demonstrate the merits of German engineering. There are also similarities in the physical aspect. In the first decade of motor racing, design went through three distinct phases ; in the second there was a line of continuous development ; but the third decade, again, may be considered as a composition in three movements.

In the opening three years the classic racing car, in the form of the P3 Alfa Romeo, the Type 59 Bugatti, and the 2.9-litre Maserati, reached its zenith. All of these cars had straight-eight engines with detachable iron cylinder blocks and used plain bearings throughout. All developed *circa* 200 b.h.p. and transmitted the drive to a rigid rear axle, albeit the P3 Alfa Romeo employed an ingenious double propeller-shaft arrangement which offered definite technical advantages in the matter of road holding.

1934 and 1935 saw the introduction of entirely novel designs from east of the Rhine, with independent suspension for all four wheels, tubular frames, rear engine mounting, and, above all, a detailed engineering technique which raised power from 200 b.h.p. to 400 b.h.p., and thus brought these cars into a class of their own. After 1934 Bugatti and Maserati virtually dropped out of competition, and although Alfa Romeo made desperate efforts to offset deficiencies in output by first-class road-worthiness they failed to meet the further tremendous advance in engine power achieved by the German cars in 1936 and 1937. Finally, in the last two years of racing emphasis shifted from gross h.p. to higher r.p.m., increased supercharge pressures and high b.m.e.p.

Road speeds rose very sharply in comparison with previous periods.

In the quarter-century spanning 1908 and 1932 the maximum speed of the road-racing car rose 36 m.p.h. from 104 m.p.h. to 140 m.p.h. This increase was matched in the next two years, and in 1935 a G.P. car averaged 195 m.p.h. over a distance of five kilometres. In short, for twenty-five years the increase in maximum speed was at the rate of 1.5 m.p.h. per annum ; from 1934 to 1936 it was at the rate of 16.4 m.p.h. per annum, a ten-fold gain.

This great acceleration in the rate of progress was almost directly proportional to the total resources made available for engineering development. Both Auto Union and Mercedes-Benz spent over £500,000 per year in 1954 values, equivalent to, say, one million man-hours, or each at least five times more than say Sunbeam in 1922-5. The methods followed by Auto Union and Mercedes-Benz varied, however, as much as did the machines which they constructed and raced.

The Mercedes-Benz main drawing-office and works was responsible for the design and production of all the racing cars which were handed over to a racing service department for development. In this section four engineers of degree status worked under Herr Uhlenhaut and there were fifty mechanics in direct charge of ten complete cars, and a further ten spare engines, with 220 fitters and mechanics available as required. The racing service department had eight diesel lorries, one equipped as a mobile work-shop and another, with a supercharged engine, for the transport of urgently required spares.

Experimental work was largely of the *ad hoc* variety and in the last three racing seasons Uhlenhaut travelled with the racing team so that he could directly observe the performance of the cars.

In the case of Auto Union a separate establishment was formed which carried out the entire process of the design, construction, and development under two heads. Design and construction was controlled by four degree status engineers working under Dr. Siebler and the development section was headed by Prof. Dr. Ing. Eberan von Eberhorst, assisted by two engineers.

During the racing season approximately 200 mechanics and fitters were available to look after approximately eight cars, four of which were generally entered for each race. In addition to the driver, each car was allocated a head mechanic and three assistants, and this car-driver-mechanic team was, as far as possible, maintained throughout a given year.

The general standard of equipment was a good deal lower with Auto Union than Mercedes-Benz, but, on the other hand, the former carried out a good deal of basic research with full instrumentation, and brakes and suspension units were given detailed component development tests. In both companies extensive use was made of pre-tested components, that is to say fuel pumps, steering gears, superchargers, and many other parts were given routine performance tests before being assembled on to the car, and Mercedes-Benz also had at their disposal a chassis dynamometer.

CHAPTER TWENTY-ONE

The Development of The Grand Prix Car

1906 - 39

THE word development in the heading of this chapter has been chosen with care and is stressed by intention. Some might think that Grand Prix cars built solely for maximum performance and with little thought for manufacturing cost and operating economy would be excellent subjects for inventive exercises which could not be justified on the production car, but this has not been so.

Nearly all the worth-while inventions of automobilism had been lodged in the Patent Office before the first Grand Prix of 1906, and the few remaining discoveries virtually coincided with the early period of Grand Prix racing. Hence, when the cars came on to the line for the first Grand Prix the principle of the spur-type gearbox had already been laid down by Panhard ; Renault employed a live rear axle in 1900 and Mercedes had developed the gate change, the honeycomb radiator, and Brasier overhead camshaft engines. Inclined overhead valves had been used by Pipe, Fiat and others, tubular frames by Gobron Brillié ; light alloys were in extensive use, having, in fact, been employed by Panhard in 1897, and applied thin copper water jackets were known. Independent front wheel suspension had been used on some of the earliest cars and was represented in the 1899 Tour de France on the 20 h.p. Bollée. Supercharging was successfully used in the U.S.A. as early as 1907, and although the introduction of independent rear suspension to racing was delayed until 1923, the de Dion axle arrangement was patented in 1894 by Count Albert de Dion. Although in this matter the relation of Trepardoux and de Dion remains, as mentioned earlier on, speculative, the original drawings which are reproduced show clearly that the scheme was allied to a steam power plant, and it is interesting that the principal patent claim of de Dion is for a half-shaft carried through the hub so that by additional spokes it can drive direct on to the rim of a wooden wheel, leaving the main spokes of the latter unstressed. The fact that the basic de Dion axle was adopted by the two leading racing-car constructors some forty-three years after the original patent application is an extreme example of the fact that the engineering story of Grand Prix racing has been primarily one of development along a continuous line of tradition, and there is literally no record of a brilliant invention making existing designs obsolete overnight.

The story of this development has been narrated chronologically in the preceding chapters of this work, but it seems desirable to analyse the history of Grand Prix racing, not only in terms of time, but also under the headings of the various factors and qualities which must be embodied in the racing car. These may be set out for clarity as follows :

(a) Laden weight.

(b) Wind resistance compounded in turn of frontal area and the drag coefficient.

(a) and *(b)* are *the fundamental contra forces* which have to be overcome by

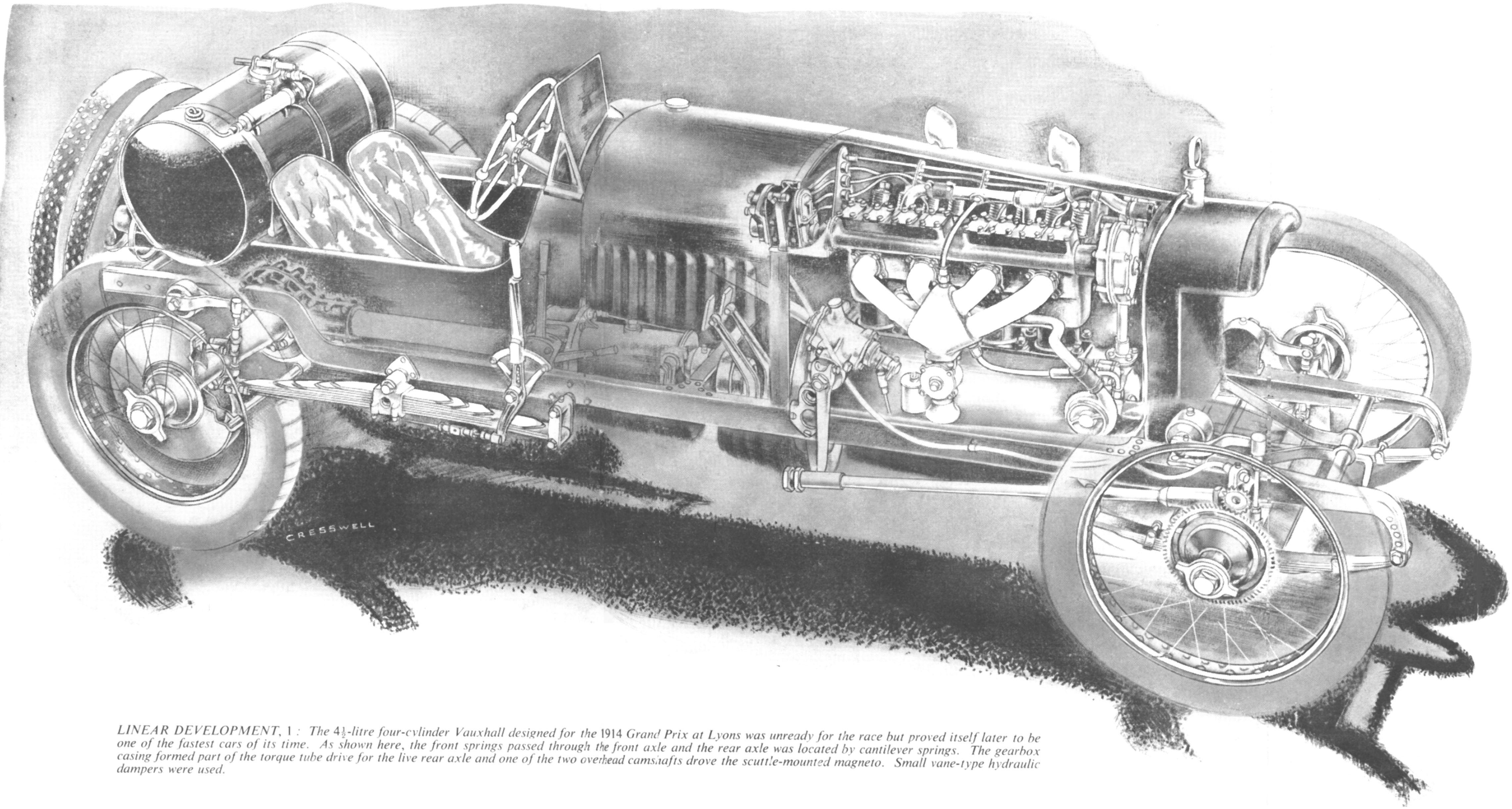
(c) Total power available at the road wheels.

In relation to *(a)* and *(b)*, *(c)* gives us :

(d) Power : Weight ratio.

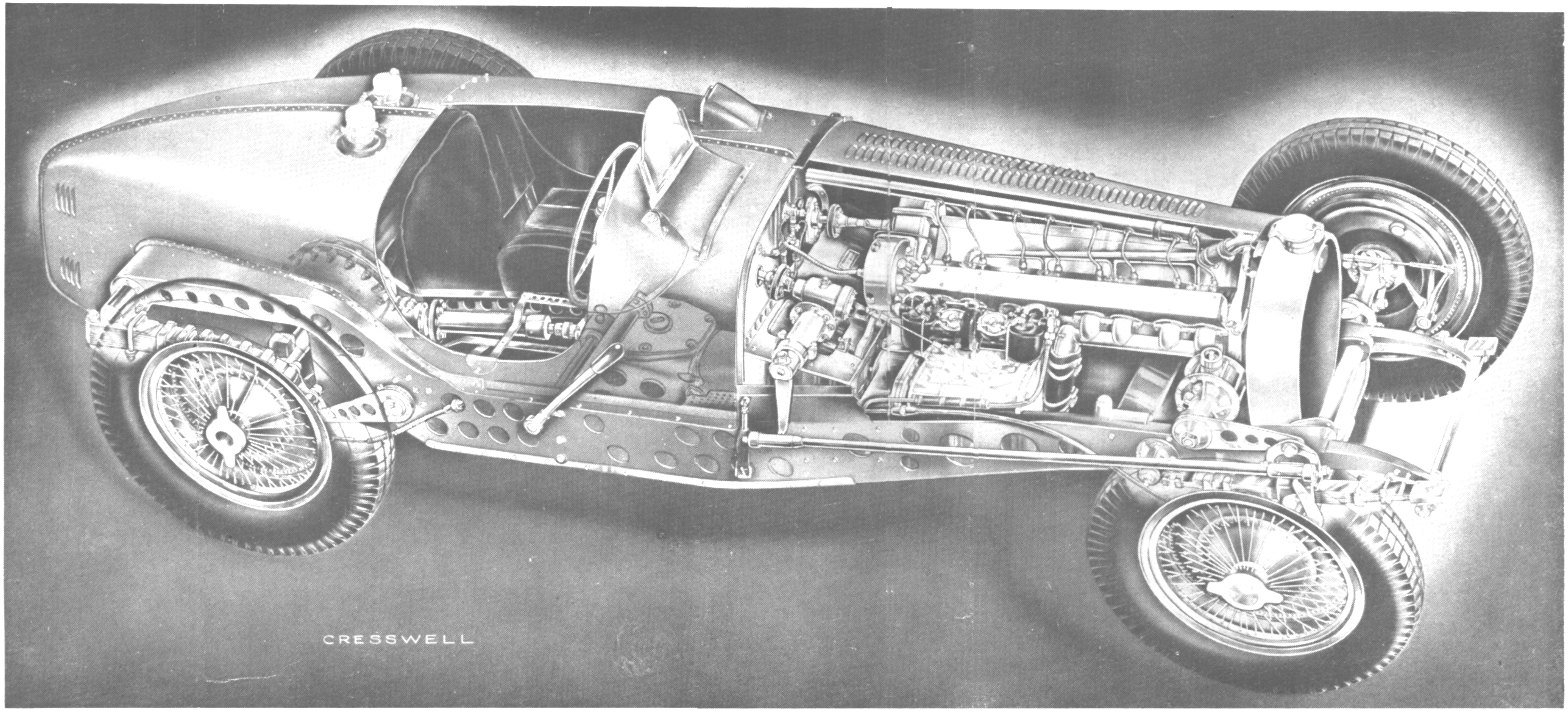
(e) Power per sq. ft. of frontal area.

THE 1914 $4\frac{1}{2}$-litre VAUXHALL



LINEAR DEVELOPMENT, 1: The $4\frac{1}{2}$-litre four-cylinder Vauxhall designed for the 1914 Grand Prix at Lyons was unready for the race but proved itself later to be one of the fastest cars of its time. As shown here, the front springs passed through the front axle and the rear axle was located by cantilever springs. The gearbox casing formed part of the torque tube drive for the live rear axle and one of the two overhead camshafts drove the scuttle-mounted magneto. Small vane-type hydraulic dampers were used.

THE 3.3-litre BUGATTI Type 59



LINEAR DEVELOPMENT, 2 : The new 750 kg. formula of 1934 saw the introductiom of wholly novel designs by Auto Union and Mercedes-Benz, but in that year they had no great margin of superiority over the fully-developed classic type as exemplified by the Type 59 Bugatti. As shown here, this car was a refined and developed version of the typical 1914 model, and was similar thereto in many respects with semi-elliptic front springs passing through the front axle, reverse cantiilever rear springs and small frictional dampers, hydraulically controlled. The live bevel rear axle was located by a torque arm and, as before, one of the double overhead camshafts was used to driive a scuttle-mounted magneto. With a 3.3-litre supercharged engine developing about twice as much power as the 1914 model, the 1934 type was about 33 per cent faster on Grand Prix circuits.

This in turn, properly interpreted, gives us basic performance figures for :

(f) Acceleration.
(g) Maximum speed.

Because Grand Prix racing has been run on roads and tracks which, of intention, have departed from geometric accuracy, it is impossible to estimate the true development of the racing car without considering certain other qualities which have no precise quantitative value. In detail these may be termed :

(h) Brakes.
(i) Steering.
(j) Suspension.
(k) Frame design.

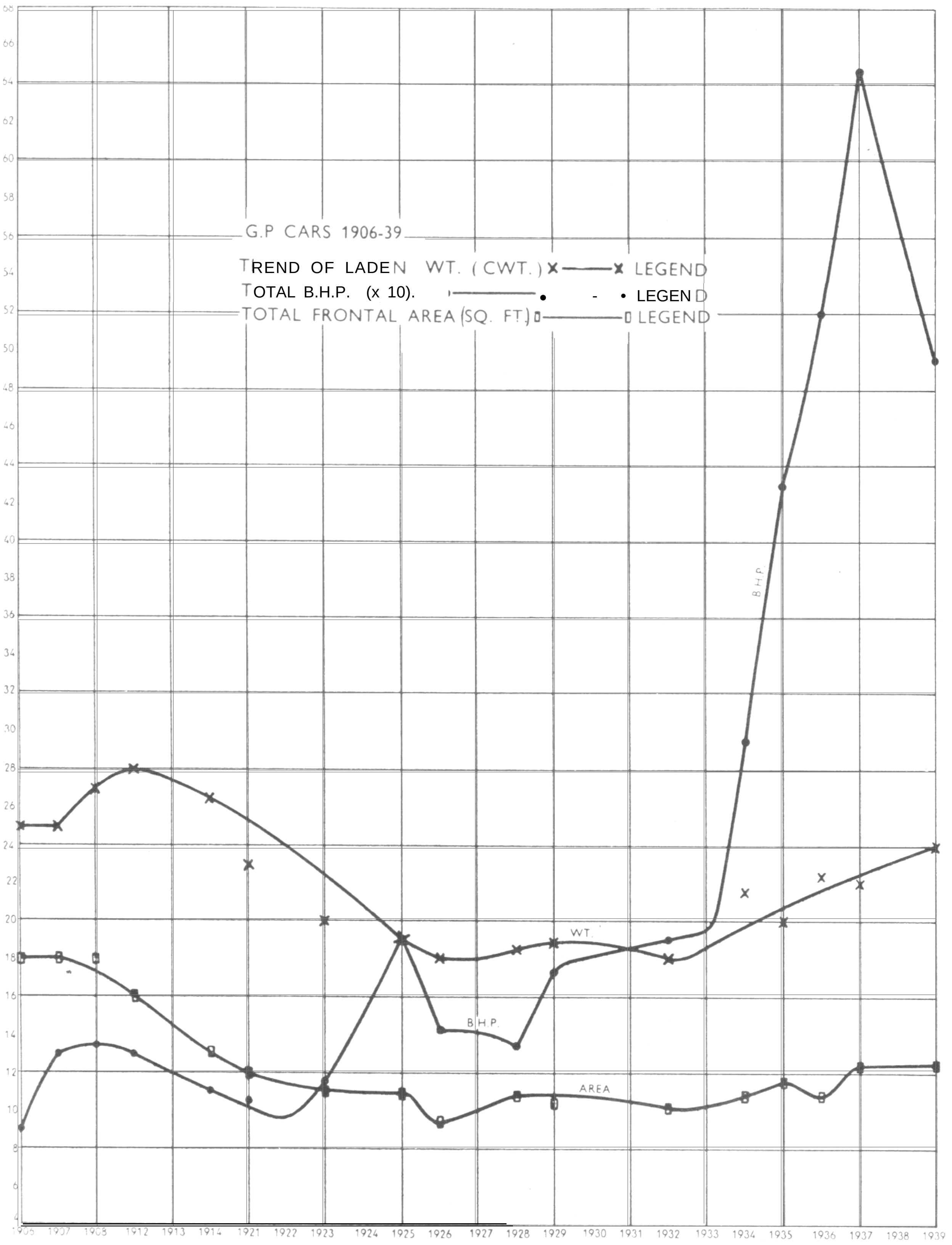
In sum these make up the factor of *Roadworthiness.*

Taking the whole of the foregoing together we can estimate the gains in average road speed of the Grand Prix cars, and we can check these estimates against relative performance of the whole range of successful designs on the road. It thus becomes possible to set up relative average indices for a circuit which can be interpreted in terms of the start allowance which a 1939 Grand Prix car would give to all its predecessors over the normal distance of a Grand Prix race (500 kilometres).

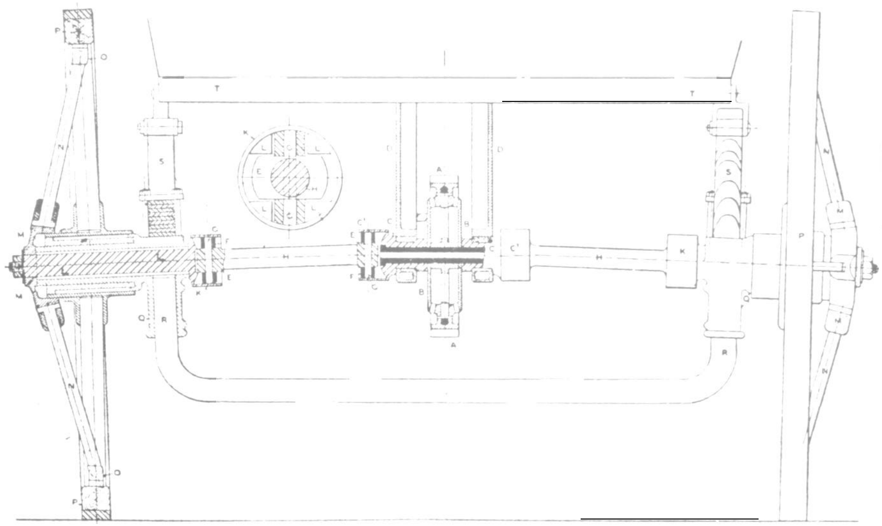
The figures for all the items *(a)* to *(e)* inclusive are to be found on various pages of this book and in the appendices thereof, but to simplify the study some graphs have been drawn based on typical Grand Prix cars as follows :

Index No.	*Car*
100	1906 Renault
104	1907 Fiat
108	1908 Mercedes
111	1912 Peugeot
117	1914 Mercedes
121	1921 Ballot
129	1923 Fiat
134	1925 Delage
137	1926 Talbot
139	1928 Bugatti
142	1929 Maserati
146	1932 Alfa Romeo
151	1934 Auto Union
150	1934-5 Mercedes-Benz
156	1936 Auto Union
157	1937 Mercedes-Benz
164	1939 Mercedes-Benz

The index numbers have reference to appendix C and it should be noted that as the design of number 150 was continued throughout 1935, 151 and 150 are deliberately inverted. Taking first the, so to speak, counteracting items of weight and windage, it will be seen that for both of these items there was in general a fairly marked drop from 1906-26 and a slight tendency to rise thereafter, so that both the laden weight and the frontal area at the end point of 1939 were slightly greater than they were in 1921. In detail there was a very big change as between 1906 and 1914, during which


G.P CARS 1906-39
TREND OF LADEN WT. (CWT.) LEGEND
TOTAL B.H.P. (x 10). LEGEND
TOTAL FRONTAL AREA (SQ. FT.) LEGEND
WT.
B.H.P.
AREA
B.H.P.
1906 1907 1908 1912 1913 1914 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939

period frontal area was reduced by nearly one-third consequent upon detail changes. Frontal area actually reached a minimum with the 1926-7 cars and thereafter increased by approximately one-third, a change occasioned by the use of larger engines and also by the belief that greater area was worthwhile if accompanied by a lower drag coefficient, although this is known to be true only with the 1939 cars.

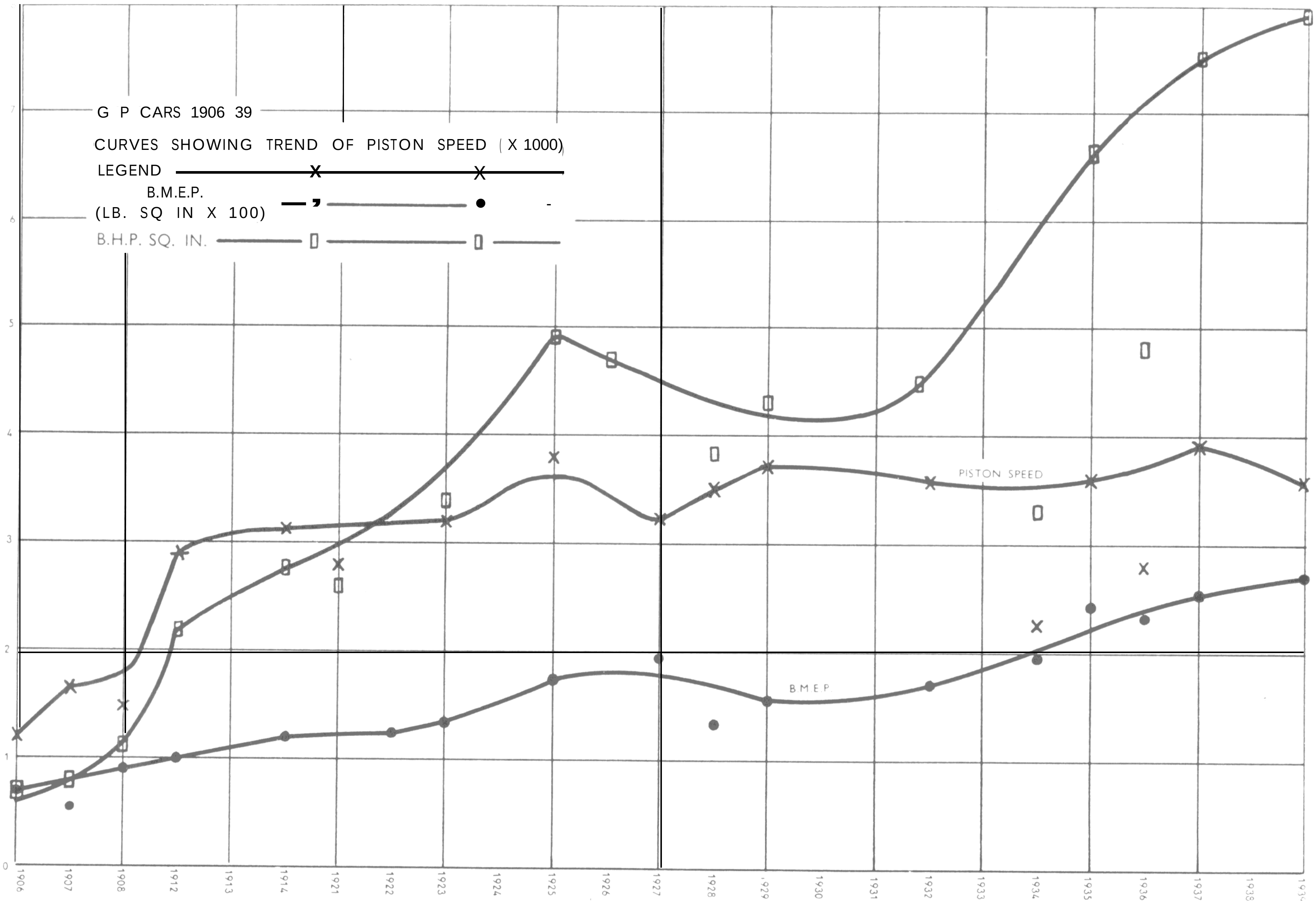


This drawing is a facsimile from the 1894 patent application made by Count de Dion and shows his arrangement of a dead axle beam with separate exposed half-shafts, each having two pot-type universal joints. The ends of each half-shaft pass through the hubs and connect with spokes engaging with the periphery of the wheel. The spokes of the wheel proper were thus relieved from driving stresses.

But (with the admitted exception of the 1939 Mercedes-Benz) the cost in h.p. of moving 1 sq. ft. of frontal area through the air has remained sensibly constant during the whole history of Grand Prix racing, despite the apparent refinement in the hull form and far greater enclosure of the crew. The explanation for this apparent paradox lies in the fact that coincident with improved body shape the drag set up by wheels and tyres of increasingly large section has grown until, on the 1939 cars, the drag of the parts attached to the hull made up over 90 per cent of the total resistance to be overcome.

The shape of the curve for laden weight is decidedly similar to that of frontal area ; and there is a steady drop from the heaviest figure realised in 1912 to the remarkably light weight of a number of vehicles built between 1926 and 1933. Subsequently unladen weights remain static, but laden weight rose by some 50 per cent by reason of a steady deterioration in fuel consumption and consequent great increase in percentage of total load accounted for by the fuel. This latter figure reached a peak in 1939 with cars carrying 88 gallons of alcohol which scaled over 600 lb. or nearly one-quarter of the all-up weight.

As a general statement we may, therefore, say that the resistance factors of windage and weight reached their lowest level in the quinquennium 1926-31 and thereafter showed a steady tendency to rise, but such increases in weight and windage were considerably more than balanced by the tremendous upswing of the b.h.p. curve, particularly after the introduction of the 750 kg. formula in 1934. The curve for total h.p. available is a regular one, an early peak being reached in 1908-12, followed by a steady decline up to 1922 and then further rapid rise to a pronounced peak in 1925,


G P CARS 1906 39
CURVES SHOWING TREND OF PISTON SPEED (X 1000)
LEGEND
B.M.E.P.
(LB. SQ IN X 100)
B.H.P. SQ. IN.
PISTON SPEED
B.M.E.P.
0
1
2
3
4
5
6
7
1906
1907
1908
1912
1913
1914
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938

a year of highly efficient, roller bearing, supercharged engines of 2-litre capacity. A reduction of engine capacity by regulation in the ensuing two years reduced the power output and as subsequent power units were built for sale to amateurs it was not until 1932-3 that successful road-racing cars were built with greater power than was possessed by the 1925 models.

Looking back to 1908 from the year 1933 there had been a gain in power of only 50 per cent, but before the end of 1934 an increment of similar proportion was recorded, and by 1937 the 1934 figure had itself been doubled. This enormous change may perhaps be more vividly presented by saying that if the front five cylinders on the 1937, eight-cylinder, Mercedes-Benz had ceased to work, the back three alone could have produced more power than any successful road-racing engine built up to 1933.

It is of interest to turn aside for a moment to consider how this great growth in power was affected.

It has been shown earlier, that a fundamental unit of engine design is horsepower per sq. in. of piston area, and that the total power depends upon this figure multiplied by the sq. in. available.

Horsepower per sq. in. is compounded of b.m.e.p. and piston speed, and for this reason a set of three curves has been prepared dealing with these factors. The lowest curve (recording b.m.e.p. figures) shows that these rose during the period under review from 70 lb. to 270 lb. per sq. in., a four-fold gain, in an almost straight line, although the supercharged roller bearing engines of 1923-7 were slightly above the mean line and the power units of 1928-35 slightly below it.

The curve for piston speed shows substantially different characteristics. In the first four Grand Prix years piston speed was doubled and by the mid-twenties the twelve-cylinder Delage engine ran at 3,700 ft./min., a figure barely exceeded in any subsequent year ; in fact, as late as 1934 the multi-cylindered, short stroke, Auto Union Grand Prix engine had a substantially lower piston speed than the 1912 Peugeot.

The curve for b.h.p. per sq. in. is drawn independently through the mean of definite plottings and given points on it may not, therefore, exactly correspond with the products of b.m.e.p. and piston speed curves immediately beneath. There is an almost straight line rise from less than one horsepower per sq. in. in 1906 to nearly 5 h.p. per sq. in. in 1925. The curve then becomes concave ; 5 h.p. per sq. in. is not exceeded for nearly ten years, after which there is a rapid, almost straight line, increment to just under 8 h.p. per sq. in. reached in 1939. It will, however, be noted that there are marked deviations from plot points in both 1934 and 1936 owing to the fact that the Auto Union cars chosen as examples for these two years combined an unusually large piston area with comparatively low piston speed and b.m.e.p.

We may now return to the study of total h.p. available as influenced by engine size. It is usual to consider an engine dimensionally in relation to the swept volume of the cylinders which was limited by regulation to 4½ litres in 1914, 3 litres in 1921, 2 litres in 1922-5, 1½ litres in 1926-7, and, in effect, 3 litres for 1938-9.

Although 1914 was the first year that capacity regulations were in force there was, nevertheless, a voluntary reduction of capacity to the extent that the swept volume of the 1912 Peugeot was under half that of the 1907 winning car. Moreover, despite the absence after 1927 of any limit on cylinder dimensions, capacity rose from the all-time

low of 1½ litres to only 3 litres in 1933, whereas the latter figure was doubled with the construction of the sixteen-cylinder C type Auto Unions in 1936 and the W125 Mercedes-Benz in 1937.

Change in piston area has been greater than variation in capacity. The fact that the two curves lie almost side by side from 1906 to 1914 is a reflex of a change in stroke : bore ratio from roughly 1 : 1 and up to *circa* 1.8 : 1, the marked divergence between them in 1925 is a corollary of the twelve-cylinder engine used by the Delage chosen as the example for this year. But the disproportionate increase in piston area in relation to capacity from 1933 onwards (and particularly in the two years 1937-9) follows upon a reversion in stroke : bore ratios to the theories held thirty years previously.

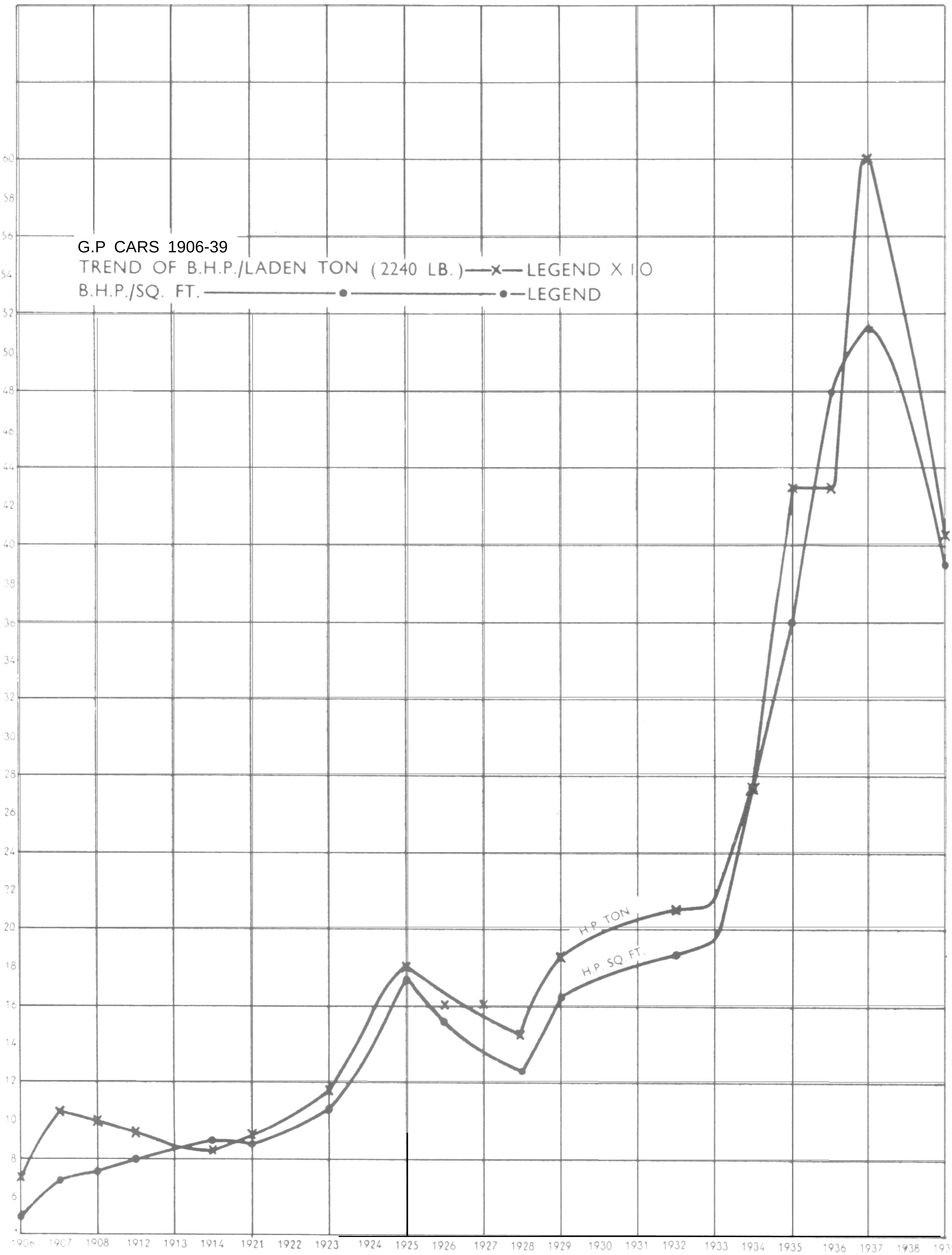
It will thus be seen that the exceptional gain in power in the 1934-7 period was derived from increments in all three basic elements of engine design ; piston area, b.m.e.p. and piston speed. The magnitude was in this order.

Having thus set out the gain in power and explained how it was obtained it is now appropriate to refer to the changes in basic road performance factors, i.e. b.h.p. per laden ton and b.h.p. per sq. ft. of frontal area.

The b.h.p./ton curve shows a quick gain in the first year and the figures recorded in 1907-8 are the highest achieved until 1922 after which designers began to extract considerably more power from engines of substantially constant weight by supercharging and enlarged piston area. After a brief decline the curve rises so that the 1908 figure is doubled by 1932, and then it takes only three years for it to be redoubled, and a further two to reach a peak which, for the Mercedes-Benz of 1937, was six times greater than the 1908 winner from the same works. As suggested by the preceding curves the figures for 1938-9 show a marked drop.

STANDING KILOMETRE SPEEDS, 1906-39

1906 16.7-litre Itala	52.4 m.p.h.	26/6/06	G.P. Circuit
1908 12-litre Mercedes	67.7 ,,	17/10/09	Tervueren
1919 4.9-litre Ballot	65.14 ,,	26/10/25	A.I. No. 7
I92 3-litre Vauxhall	69.75 ,,	6/10/25,	AI. No. 7
1925 2-litre Delage	79.39 ,,	11/10/25	A.I. No. 7
1926 2.3-litre Bugatti 35B	71.56 ,,	26/4/27,	3R
1926 1.5-litre Talbot	81.55 ,,	5/9/26,	AI. No. 10
1929 2-litre Bugatti 35C	80.44 ,,	19/5/30	R.A.C.4
1932 2-litre Bugatti, Type 51	81.49 ,,	4/8/33	A.I. 211
1934 2.9-litre Maserati	88.87 ,,	23/3/34	A.I. 231
1934 4.95-litre Auto Union	101.56 ,,	20/10/34	A.I. 254
1937 6-litre Auto Union	117.3 ,,	26/10/37	A.I. 304
1939 3-litre Mercedes-Benz	110.2 ,,	14/2/39,	A.I. 318


G.P CARS 1906-39
TREND OF B.H.P./LADEN TON (2240 LB.) —×— LEGEND X 10
B.H.P./SQ. FT. —•— LEGEND
H.P. TON
H.P. SQ. FT.
1906 1907 1908 1912 1913 1914 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938

We have previously seen how the curves for weight, and frontal area follow closely together, and it follows that the h.p. per sq. ft. curve must also lie close to the h.p./ton curve. In the early days of racing the rate of improvement under this head was rather greater than it was for the power : weight ratio, but generally speaking what applies to one applies also to the other.

It is, unfortunately, not possible to relate the h.p./ton curve with exact figures for acceleration, but some idea of the overall changes in acceleration times can be derived from a study of the speeds put up by Grand Prix cars during various record-breaking performances. These are set out in a table on a preceding page.

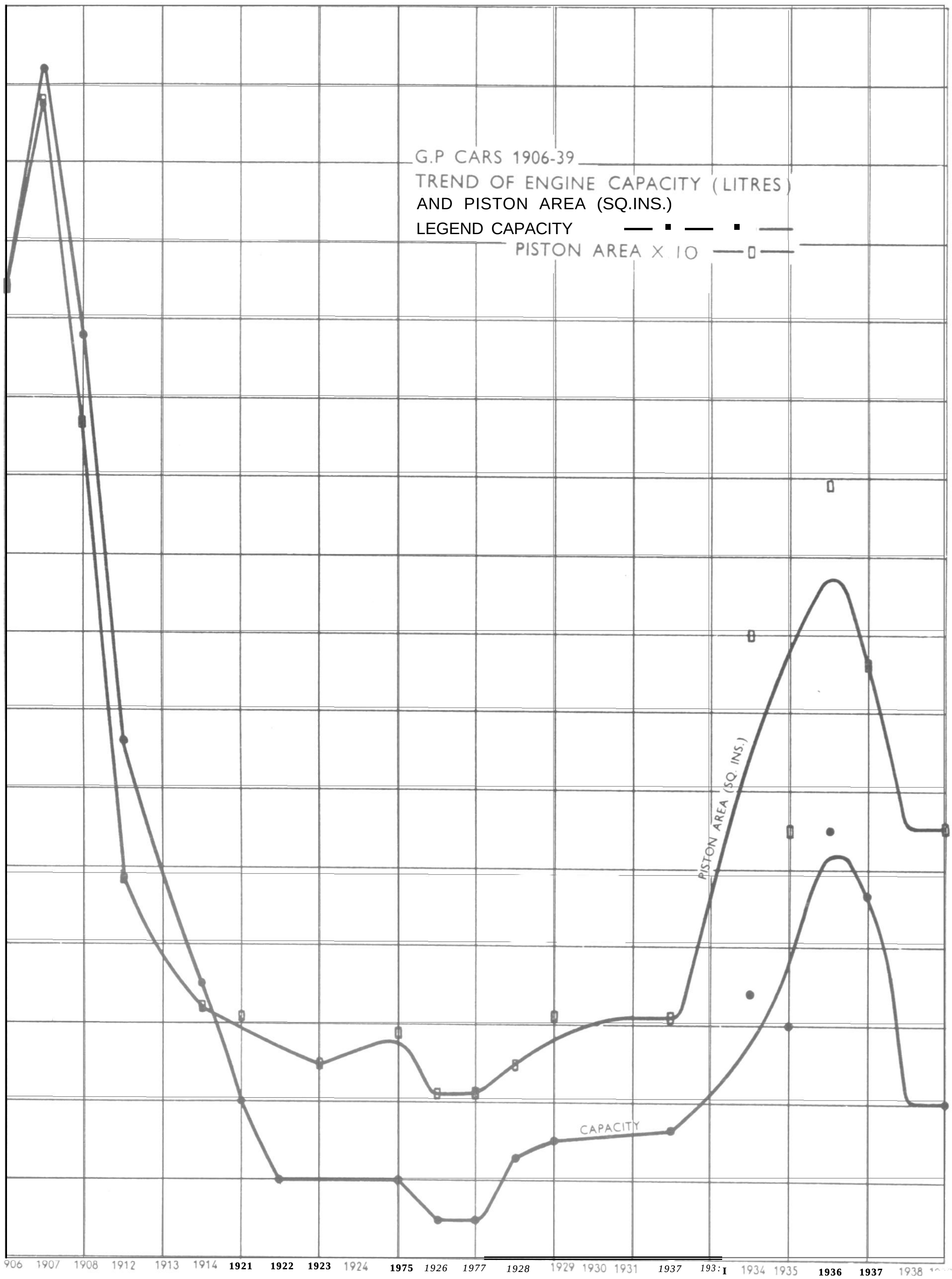
In laying out the ordinates for the maximum speed curve we have exact measurements of time and distance for the 1906 Renault, 1908 Mercedes, 1912 Peugeot, 1920 Ballot, 1925 Delage, 1926 Talbot, 1928 Bugatti, 1935-6 Auto Union, and the Mercedes-Benz cars of 1937, ‘38 and ‘39. The figures for the 1907 Fiat, 1914 Mercedes, 1923 Fiat, 1929 Maserati, 1932 Alfa Romeo and the Mercedes-Benz and Auto Union of 1934-5 can be estimated with a reasonable degree of accuracy.

If we assume that the drag factor for all Grand Prix cars has remained constant (at about Cw = 0.6) then maximum speed should vary as the cube root of the hp./sq. ft. The gap between theory and practice is small. The biggest discrepancy (some 8 per cent) is in 1939, in which year the engineers, both of Mercedes-Benz (the selected example) and Auto Union (which had a comparable power factor and maximum speed) were impelled towards a serious study of the drag problem following upon a forced diminution of engine capacity and horsepower. One is less astonished by this exception to the general rule than by the extraordinarily close conformity of all the other vehicles to the cube root law. That vehicles of such widely varying frontal aspect and general body lines as the 1906 Renault and 1912 Peugeot, to take two early examples, and the 1923 Fiat and 1926 Talbot, as representatives of the middle '20's, and the 1932 Alfa Romeo should, as proved by their obedience to the cube law within 2 per cent, have had the same drag coefficient within 6 per cent is almost unbelievable.

From 1934 to 1937 there are more marked divergences between the two curves, but in these years potential maximum speed had risen so much that it was worth sacrificing time gained by travelling as fast as possible in return for improved acceleration. For example, on no circuit would it be possible to travel for more than two miles in all at maximum speed, taking 40 seconds at 180 m.p.h. An average 200 m.p.h. over two miles would save only 4 secs. and better acceleration obtained by lower gearing could easily offset so small a time saving.

It is the specific characteristic of the road-racing car that lap speed is the criterion by which it is judged and although, as we shall see later, there is statistically a close connection between this and maximum speed, the link is through the common factor of engine power and the relationship may be disturbed by any or all of the factors set out under the headings *(h)* to *(k)*, which have been summarised as “ roadworthiness.” In particular, braking power may be considered as equal to engine power in its effect on averages over difficult circuits.

Some drivers, notably Nuvolari, have developed an intentionally forced skid prior to a corner for the double effect of slowing the car and of placing it at the correct angle for a straightline departure down the ensuing section of the road. But it has been estimated that with normal driving the brakes are used upon 30 per cent of a road-racing course and, of course, the energy to be dissipated rose very much with


G.P CARS 1906-39
TREND OF ENGINE CAPACITY (LITRES)
AND PISTON AREA (SQ.INS.)
LEGEND CAPACITY
PISTON AREA X 10
PISTON AREA (SQ. INS.)
CAPACITY
906 1907 1908 1912 1913 1914 1921 1922 1923 1924 1975 1926 1977 1928 1929 1930 1931 1937 193: I 1934 1935 1936 1937 1938

increased maximum speeds, for the inertia of the car varies as the square of the speed. Hence as much energy is dissipated in reducing speed from 180 m.p.h. to 148 m.p.h. as is in lowering the speed from 110 m.p.h. to 45 m.p.h. Wheel diameter imposes a ceiling on the available brake drum area through which this energy may be dissipated in the form of heat.

It would seem impossible to build conventional brakes with an internal surface area of more than 600 sq. in., but on the pre-1914 Grand Prix cars the brake area was high in relation to weight as there were three drums, two on each wheel and one placed behind the gearbox operating through the transmission. All three, however, were connected to the rear wheels only, and thus under the most favourable conditions of brake distribution and friction coefficient the maximum rate of retardation could not exceed 0.5 g. It is doubtful if more than 0.2 g. was realised when braking from high speeds, although it was part of the established technique of the time to lock the rear wheels just before entering a sharp corner at moderate speeds, thereby provoking a skid which assisted the car round the bend.

The introduction of brakes on all four wheels to the road-racing cars of 1914 raised the theoretical rate of retardation to 1.0 g., but it is improbable that the maximum on the road was more than 0.3 g., and although no detail statistics have ever been published on braking rates used in races, it seems unlikely that 0.4 g. has been exceeded except in emergencies.

Front wheel brakes led to a speed gain of the order of 5 per cent for a given lap, but the improvement in overall average speeds from the start to the finish of a race has probably been a good deal higher and most of the development from 1914-39 has been towards improving the long-term effectiveness of the braking system rather than in the search for the shortest possible stopping distance.

The lines of work have been towards maximum retardation for a given pedal pressure, firstly by relatively complicated servo mechanisms and latterly by the use of the Lockheed hydraulic system.

Improved brake linings (there was marked development between 1928-31 and 1937-9), the use of two or even four leading shoes within the drum and a steady increase in the diameter, width and stiffness of drums, have all been means whereby sustained braking power has matched increases in power and maximum speed, but we have no possibility of estimating the benefit of a 1939 braking system if it had been available to the designers of cars in previous decades. The study of racing car design does, however, show that between 1922 and 1934 the additional unsprung weight caused by brake drums attached to the ends of a rigid front axle caused serious embarrassment and led to a great increase in spring stiffness. In some cases (notably the P3 Alfa Romeo) radius arms were resorted to so as to maintain constant castor angle, but this did not affect the risk of front axle tramp at high speeds, a danger which, with orthodox systems, could only be suppressed by short, stiff, springs with heavy friction damping.

A study of moving pictures taken of the pre-1914 races shows that due to the low unsprung weight (characteristic of brakeless front axles and chain drive with dead rear axles) the cars were softly sprung, and, when travelling at low speeds over rough roads, as in the controlled passage through certain towns, responded with a low period-

icity. Studies of this kind show also that the cars showed a marked tendency to run wide on the corners and such accidents as occurred were almost invariably the result of the driver's sheer inability to pull the car round the required radius, with the result that the car struck the outer bank or retaining wall. Between 1910 and 1914, however, drivers established the technique of imposing artificial oversteer upon fundamentally understeering vehicles. This they did by using the powerful transmission brakes of the time temporarily to lock the rear wheels, and this, in conjunction with the loose road surfaces characteristic of this period, made it possible literally to slide the car round a sharp corner.

The comparatively poor road surfaces, and the limited stopping power of the earlier racing cars made all-round roadworthiness a particularly important quality in the attainment of success. The very fast overhead camshaft Clement-Bayard Grand Prix cars of 1908 were, for example, handicapped by too high a centre of gravity which gave them a high roll angle, and an unpleasant, or even dangerous, wander at high speed on the straight. This last-named characteristic was also true of the 1906-8 Renault cars. These ran without a differential, and the drivers remarked that it was impossible to hold the cars on a straight course ; they simply demanded a long wave oscillation which had to be checked instantly it showed signs of taking the car off the road.

All the Henri-designed Peugeots and their derivatives, Sunbeam and Ballot, with their sub-frame-mounted engines and gearboxes, reflected in their behaviour on the road the inherent flexibility of the main frame and lack of torsional stiffness, qualities which made it necessary to " persuade " the cars round a corner as they whipped and weaved beneath the driver's hand. By contrast, the various Mercedes Grand Prix cars all showed a remarkable rigidity which made it possible for the driver to point the car exactly where he wished it to go. Within the laws of centrifugal force, it went precisely there.

Between 1921 and 1936 increasing unsprung weight arising from the use of front brakes, and the retention of beam axles and leaf springs made it necessary to reduce axle movement to an absolute minimum. One consequence of this was the obvious one of giving the driver or mechanic an extremely punishing ride ; the other was to produce basically oversteering cars which were maintained in a straight line only by constant correction on the steering wheels. These cars showed a natural trend towards rear wheel skids on bends and the drivers fixed the attitude of the car in a radius by the degree of counter-steering that was employed.

One of the earliest cars to exemplify this basic change in behaviour was the Indianapolis Sunbeam which showed a really vicious rear-end breakaway which alarmed, and with good reason, even highly experienced drivers.

From 1934 onwards the control of cars in this fashion became increasingly difficult for, with gross output rising from some 200 h.p. to over 400 h.p., the corresponding increase in surplus power made it all too easy to generate wheel spin which exaggerated the inherent oversteering characteristics.

Not until 1937 and thereafter was this steady growth of engine power put to good purpose. It was then combined with much softer suspension and with cars endowed with the old-fashioned basic understeer. For the first time, therefore, it became possible for drivers to control the position of the car on the road with a high degree of accuracy

by using the technique of balancing the understeer by a controlled degree of wheel spin which tended to swing the rear end of the car slightly outwards. In other words, the technique of the four-wheel drift, which could be practised at moderate speeds on the 100 h.p. racing cars of 1906-14, became an established technique for the 450 h.p. cars of 1939 at speeds lying within the 120-160 m.p.h. band.

There was, further, a deterioration in overall frame stiffness, particularly in torsion, following upon the general adoption of unit construction for engine and gearbox in 1922. Four-point mounting of the crankcase on the early cars provided an immensely stiff bracing for the front section of the frame, whilst similar mounting for the centrally placed gearbox gave additional benefits. On some cars built in the late '20's, notably the 1½-litre Delage, the mounting of the combined engine and gearbox relieved these components from bending moments but, at the same time, eliminated almost all cross-bracing between the frame side-rails.

Bugatti stood alone in his appreciation of the benefits to be derived from stiff frames, and on his cars the sump formed a brace for the front end of the car, and the dash structure effectively tied together the centre section. Additionally, the side members were correctly proportioned as a beam. This led to the comparatively low power, low performance Type 35 Bugatti scoring against faster cars and to a considerable detail improvement by other manufacturers in the period 1929-32. No radical changes in racing car design can be discerned in this period, but the overall effectiveness of the vehicles was raised and lap speeds increased within a given framework of engine output, acceleration and maximum speed by about 6 per cent.

The introduction of independent suspension to all four wheels by Mercedes-Benz and Auto Union was a revolutionary change which made it possible usefully to extend engine output from the 200 b.h.p. which had proved the maximum which could advantageously be employed on the older type of car to 400 h.p. and more. By this bold stroke unsprung weight was lowered and the geometry of the steering improved, and, perhaps most important, the transverse torque effect on the rear wheels was eliminated.

In the initial stages, however, the range of independent wheel movement was not much greater than that provided on cars with rigid axles, and although box section and tubular frames were employed there is evidence that these were not really adequate in torsional stiffness. Additionally, the use by both parties of the swing axle system at the back substantially exaggerated existing oversteer tendencies. For all these reasons the potential benefits of independent suspension were not fully realised ; on the contrary, there is abundant statistical evidence that, power for power, the " classic " type of car remained the more roadworthy until 1935.

That this should be so was in accord with previous experience for although the theoretical benefits of independent suspension (and of the front wheels in particular) are unquestionable it is undeniable that earlier racing cars so equipped (e.g. the 1899 20 h.p. Bollée, the 1907-12 Sizaire Naudin, 1924 Sima Violet and 1925-7 Alvis, the two last with front drive) seemingly secured no great advantage over their beam axled contemporaries. In this matter the usage of Alfa Romeo with their decade of experience prior to 1934 is perhaps even more important than the practice of the German companies, both of whom started with clean sheets of paper and put theory directly into practice with no alternative practical experiments. The Italians, however, were converted

to I.F.S. in mid-1935, and then to rear swing axle in late 1935. But it was the advent in 1937 of W.125 Mercedes-Benz which marked the biggest single advance in chassis design and roadworthiness in the whole history of Grand Prix racing. By using soft springs and large wheel movements at the front of the car and the de Dion axle system at the back, overall stability of ride, a torque-free drive system, and basic under-steer characteristics were combined and these qualities were enhanced on the 1938-9 3-litre cars by markedly lowering the centre of gravity, still further reducing the stiffness of the suspension, and by hydraulic in place of friction damping. Development on the Auto Union chassis followed along similar lines, but these cars must be considered exceptional by reason of their use of rear (or more accurately centred) engine mounting. This fact considerably complicates assessment of their technical merit.

From the viewpoint of engine power in relation to weight and frontal area, rear engine mounting has many advantages to offer but it has been suggested that rear-engined cars with a central grouping of masses have inferior handling characteristics due to lower polar moment of inertia, leading to very rapid changes of attitude on the road when the car is subjected to overriding external forces. The correctness of this view has been challenged and some figures have been set out comparing a rear-engined Auto Union car with a front-engined Mercedes-Benz using absolute units of comparison thus :

	Auto Union 6-litre	Mercedes-Benz W165
Weight (cwt.)	22.1	17.2
Inertia moment around front axle centre (lb.-ft.-secs.^{2})	3,050	1,485
Inertia radius (ft.)	5.93	4.67
Relation of inertia radius to wheelbase	0.68	0.621
Angular acceleration around front axle centre (Radians,kecs.z).	2.19	2.61
Inertia moment around centre of gravity (lb.-ft.-secs2)	815	505
Inertia radius (ft.)	3.04	2.72
Relation inertia radius to wheelbase	0.354	0.36
Angular acceleration around centre of gravity (Radians/secs.^{2})	13.64	15.28

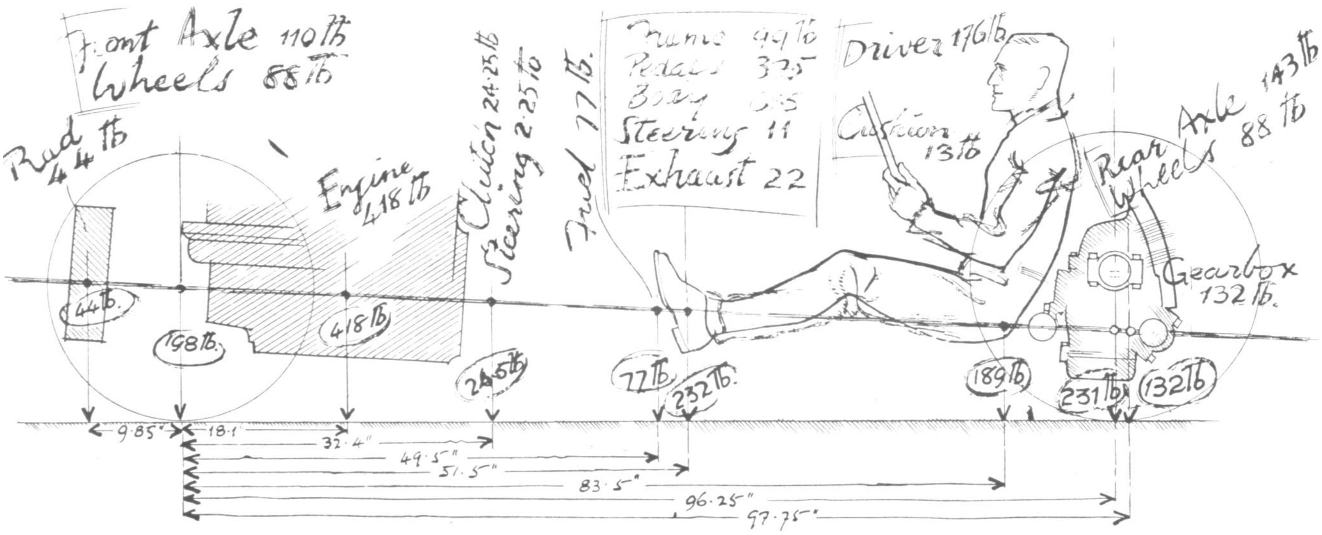
An analysis on these lines does not, however, embrace every factor to be considered, for it ignores the relation between the driver and the car.

When driving a racing car the limits of adhesion on the driving wheels are frequently overstepped and the tail of the car develops an angular acceleration in relation to the nose. The driver not only perceives a change in attitude on the road with his eye, but also responds to, and weighs the magnitude of, the acceleration by physical impulses despatched from his seat to the brain. It is evident that if he sits in the centre of the car his sideways acceleration will be lowered and his physical reaction correspondingly reduced. Correct driving of a rear-engined car with a mid-point seating position demands, therefore, a driver of unusual sensitivity, and it is significant that only three people have been discovered who could drive such a car to the limit of its power.

For this reason the front-engined car is not likely to be displaced and, to summarise, there have been four major developments in the chassis design of this type. These were : the introduction of front-wheel brakes in 1914, a general improvement in brake linings and drums, coupled with detail refinements in chassis design in the period 1923-32 ; the introduction of independent suspension to Grand Prix racing in 1934 and, finally, the development of the softly sprung car with de Dion rear axle and low centre of gravity in 1938-9.

The two first examples put chassis design ahead of engine performance and thus by themselves added 5 per cent and 6 per cent respectively to lap speeds.

In the two more recent changes improved roadworthiness was not a profitable end in itself, but merely a means of keeping a balance with enormously enhanced engine power. Statistics show that for the first three racing seasons of the 750 kg. formula road holding and cornering power was not, in fact, equal to the engine power and maximum speeds obtainable, but this deficiency was corrected in the 3-litre cars of 1938 and 1939.



During the period 1937-9 the engineers responsible for Mercedes-Benz racing cars made every endeavour to dispose the weight of the car equally on the front and rear axles and to mass the weight at the front and back of the car so as to give the largest possible polar moment of inertia. This drawing shows the weight distribution on the I½-litre Type 165 model which was a scaled-down version of the 1939 Type 163 Grand Prix car.

We have now before us a broad picture of the main lines of racing car development over a period of more than thirty years, but it may be appropriate to make some brief reference to changes in the materials with which the cars were made.

The Grand Prix racing car has always been an-assembly of ferrous components, but whereas the pre-1912 cars were built mainly of cast-iron and mild steel, nickel-steel, under the influence of Peugeot, came to be used in the 1912-4 period and the use of forged steel barrels by Mercedes in 1914 was a powerful influence on future engine construction. Subsequent metallurgic developments were mainly along the lines of alloying, not only nickel, but also chrome, vanadium and molybdenum to provide

forgings offering up to 100 tons tensile strength for shafts, connecting rods, etc., and thin wall tubes (which could readily be welded) for framework. Successive changes of piston material from cast-iron to steel and finally to light alloy were coupled with the rise in piston speed which has been presented graphically. As with steel, so with non-ferrous parts, improvement in physical qualities has been effected by the use of alloys, particularly copper or silicon, and great benefits were obtained in the maintenance of strength at elevated temperatures. In this respect special note should be taken of the development of austenitic steels for exhaust valves and also to the employment of hollow valve stems filled with sodium or mercury as a means of improving heat transfer from the head to the valve stem.

However, none of these modifications in the physical strength of the materials made any sensible difference to the moduli of elasticity thereof and one may legitimately conceive that a major change in the construction of the racing car has been the shift from strength to stiffness as a basis of design. Mention has already been made of this aspect in respect of torsional stiffness of the chassis but the development was no less active in the matter of the main structure. Gudgeon pin diameter can be taken as a typical example. The gudgeon pin of the 1913 Peugeot was 16 mm. (20.5 per cent of the bore diameter), but on the 1920-l Ballot designed by the same man the size was 20 mm. (i.e. had risen to 25 per cent) so that the beam stiffness increased by more than 50 per cent, without taking into account a 15 per cent reduction in length and an individual piston area diminished by 30 per cent. Similarly, the 1920 Ballot, 1932 Alfa Romeo and 1938 Auto Union cars had, within a limit of 5 per cent, the same cylinder diameters, but the crankpin dimensions were 42 mm., 52 mm., and 66 mm. respectively, a stiffness ratio of 1.0, 1.54 and 2.46 respectively.

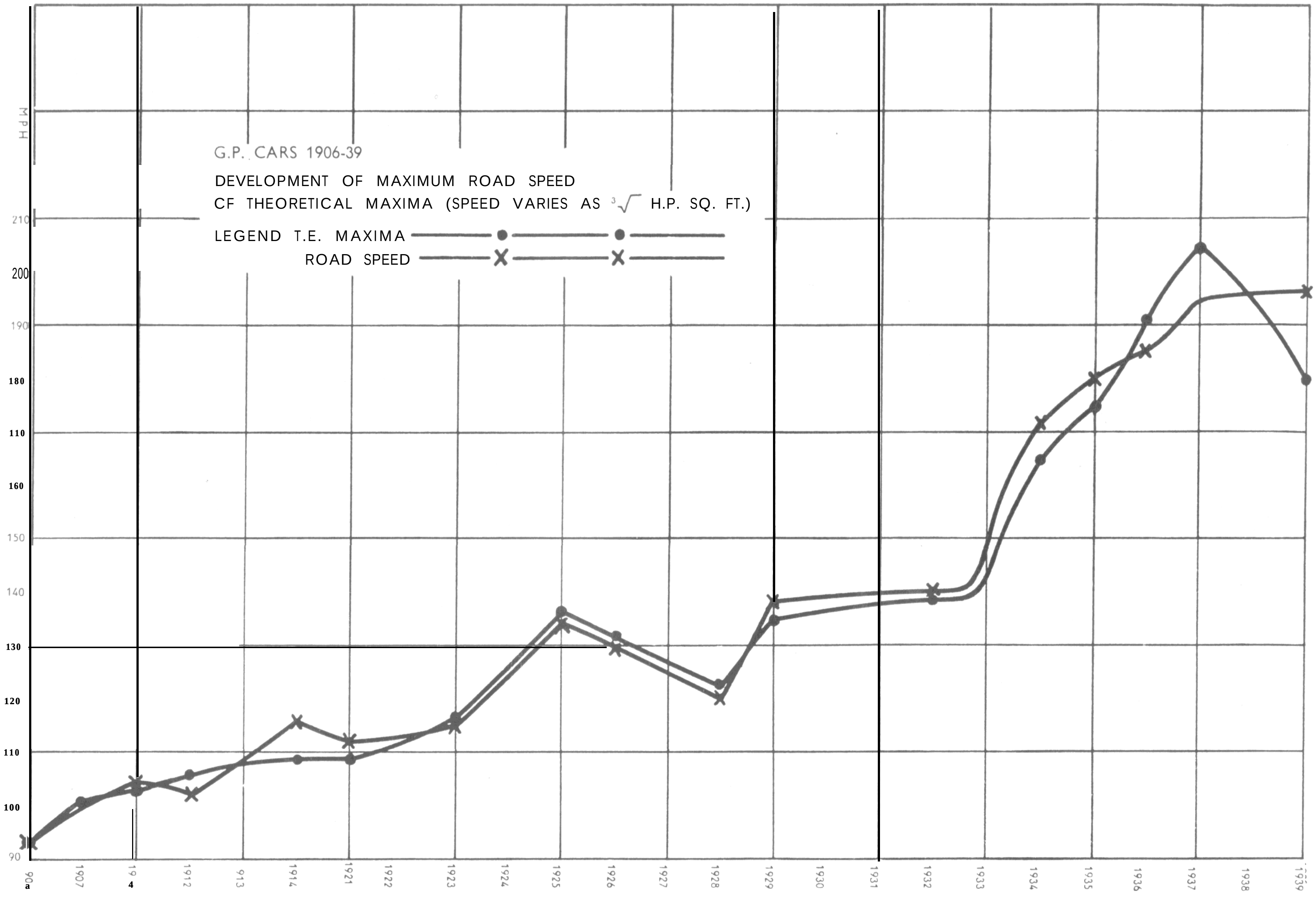
In sum, one of the principal lessons learned by engineers was that mechanical failures were more often caused by distortion and local overloading than they were by stressing above the physical strength of the material used:

Developments in the consumables of tyres and fuel have been just as important as any change in the materials used for the structure of the car.

The first big change in tyre design occurred between 1908 and 1912 with the development of the cord in place of the fabric base, and whereas in the 1908 Grand Prix the winner stopped twelve times for tyres in 477 miles, in 1914 at Lyons the victorious car made only four wheel changes in 466 miles. Later there was constant development in design such as the supersession in 1925 of the beaded edge by the straight edge with wired-on method of securing the tyre to the rim, also by improvement of materials, and increases in section.

It was proved in 1937 that in conditions where a racing car tyre would survive l50 miles the normal touring car cover would run barely a twentieth of this distance, and despite almost incalculably higher stressing, tyre life was maintained at about 200 miles on the rear covers for the whole period of 1925-39.

A race for cars using alcohol fuel was organised as early as 1902 and it was consistently employed by Gobron Brillié in their racing and record-breaking cars, one of which was (in 1904) the first to exceed 100 m.p.h. with an internal combustion engine. But the specialised technique of high compression ratios and very rich mixtures



M P H
G.P. CARS 1906-39
DEVELOPMENT OF MAXIMUM ROAD SPEED
CF THEORETICAL MAXIMA (SPEED VARIES AS $\sqrt[3]{\ }$ H.P. SQ. FT.)
LEGEND T.E. MAXIMA
ROAD SPEED
210
200
190
180
110
160
150
140
130
120
110
100
90
1907
1912
1914
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939

was a late development, and on all the early unsupercharged cars the limit of power was set not by thermal problems but by mechanical disabilities which alcohol was powerless to relieve.

Petrol of not more than 65-70 octane value was put in the tank of the Grand Prix cars built before 1921 with a corresponding limitation of compression ratio to at most 6.0 : 1. In the next ten years blends of approximately equal amounts of petrol, benzole and alcohol permitted up to 10 lb. boost on supercharged engines without reduction in compression ratio. The general use of fuels with low alcohol content persisted on low boost, and, for example, all the eight-cylinder Mercedes-Benz engines were tested (but not raced) on petrol-benzole mixture and Alfa Romeo won the 1934 A.V.U.S. race using leaded petrol and benzole.

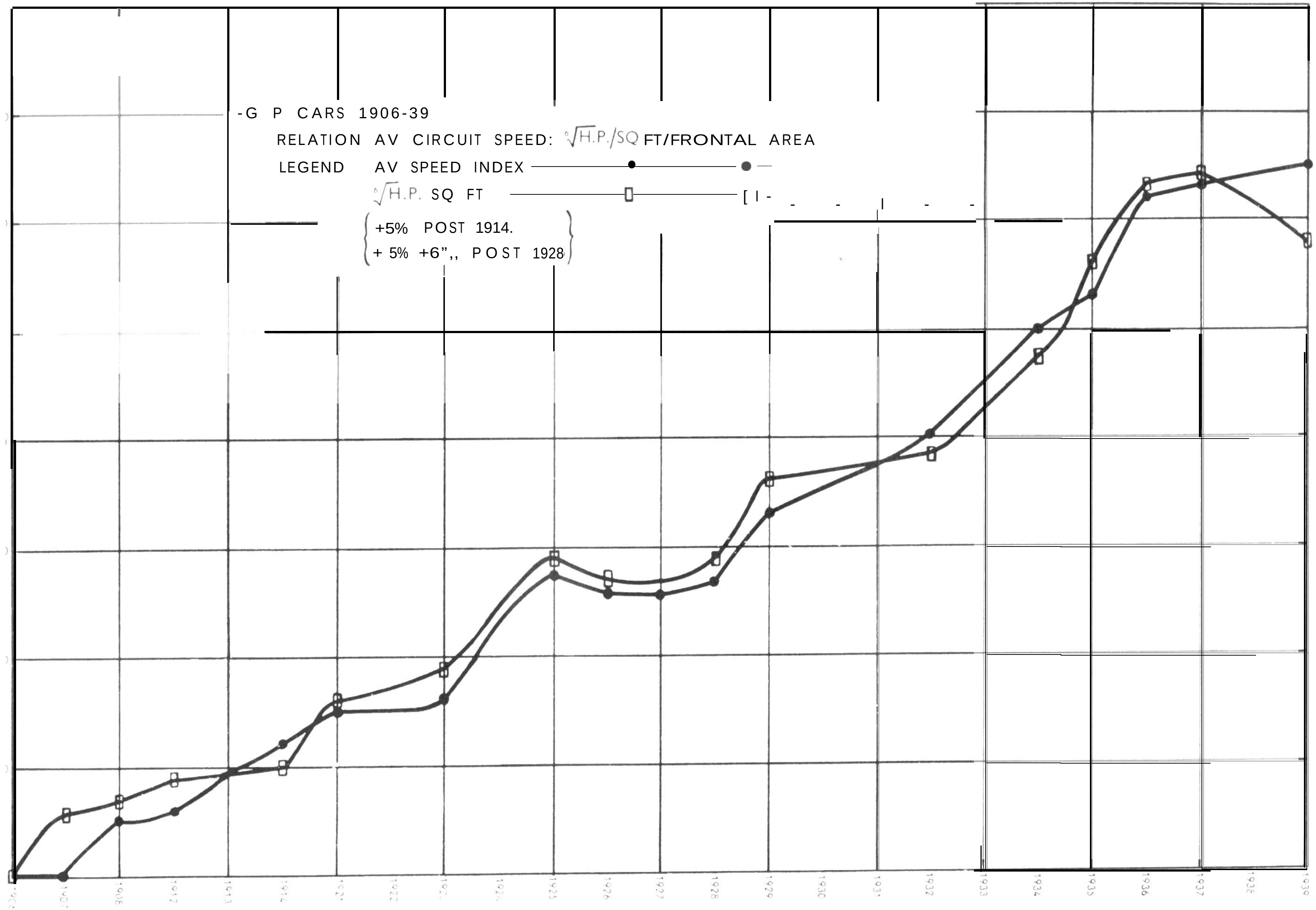
The design of engines with very high boost pressure and specific outputs for the years 1938 and 1939 made it impossible to continue with this type of fuel which gave way to the use of almost pure alcohol with the addition of small percentages of acetone, ether, etc., to give easy starting. The high alcohol content was required not merely to inhibit detonation, but also to act as an internal coolant in which respect a very high latent heat of vaporization and an ability to burn with a very low air ratio was invaluable.

Specialised components such as superchargers, magnetos, dampers, carburetters and sparking plugs occupy a mid-position between raw materials and the completed car, and the vehicle as an ensemble has owed much to companies specialising in the manufacture of such parts. But with the possible exception of the change from friction damping to hydraulic shock absorbers the fundaments of design were established in the first decade of Grand Prix racing, and progress has in components, also, been strictly a matter of *ad hoc* development.

Having thus given a brief summary of the changes made in the vehicle it is now appropriate to consider the effect of these continuous modifications as reflected in road performance. It is shown in the third section of this book that it is possible so to compare performance of cars over known circuits as to build up a reasonably accurate picture of relative lap speeds over the past fifty years. This process gives ground for the belief that, for a given type of car, lap speed varies as the sixth root of the h.p. per sq. ft., that is to say as the square root of the potential maximum speed. It is, therefore, possible to present two curves, one showing the anticipated relations for lap speed between the various cars which have been taken as examples and the other the actual measured performance as recorded in events.

As previously mentioned, development in braking and chassis design produced gains of 5 per cent and 6 per cent respectively in 1914 and *circa* 1928, and the theoretical curve has been adjusted to take this into account.

The coincidence of the theoretical and realised average speed curves is even more remarkable than the close approximation, already demonstrated, between the maximum speeds theoretically to be expected and actually obtained. The facts about maxima reflect a Natural Law whereas the sixth root relation between h.p./sq. ft. and average speed index is purely empiric. That it holds good for so many cars over so long a period of time is, however, the best proof that it is a useful tool for the engineer engaged in predicting potential circuit speeds.



-G P CARS 1906-39
RELATION AV CIRCUIT SPEED: $\sqrt[6]{\text{H.P./SQ}}$ FT/FRONTAL AREA
LEGEND AV SPEED INDEX
$\sqrt[6]{\text{H.P.}}$ SQ FT
+5% POST 1914.
+ 5% +6",, POST 1928
1908
1913
1925
1926
1927
1928
1929
1932
1933
1934
1936
1937
1939

The character of both curves follows the by now familiar pattern, that is to say, there is a quick upward movement between 1906 and 1914, and then little or no improvement until 1923, when the supercharged Fiat predicts a pronounced change. In the next ten years the curve takes the form of an almost straight line with an average annual increment of just under 2 per cent per annum. In 1934-5, the first two years of the 750 kg. formula, this rate was nearly trebled, and the progress during the five racing seasons which formed the life of the formula was virtually equal to that which has been seen in the previous ten years, although from the very nature of a sixth root curve a point of diminishing returns had obviously been reached.

The 1939 3-litre cars reached the highest performance index of their time, but expressed merely in terms of units the rise in average speed of 65 per cent as between 1906 and 1939 may appear as no outstanding achievement. The order of progress may be better appreciated if translated into a handicap allowance over, say, the Rheims circuit used for the 1939 Grand Prix. On this occasion the Type W163 3-litre Mercedes-Benz, driven by Lang, lapped the course at 117.5 m.p.h., and on this basis we might reasonably expect a single lap speed for the other cars and models which have been prominent in Grand Prix racing to be as shown in a succeeding table.

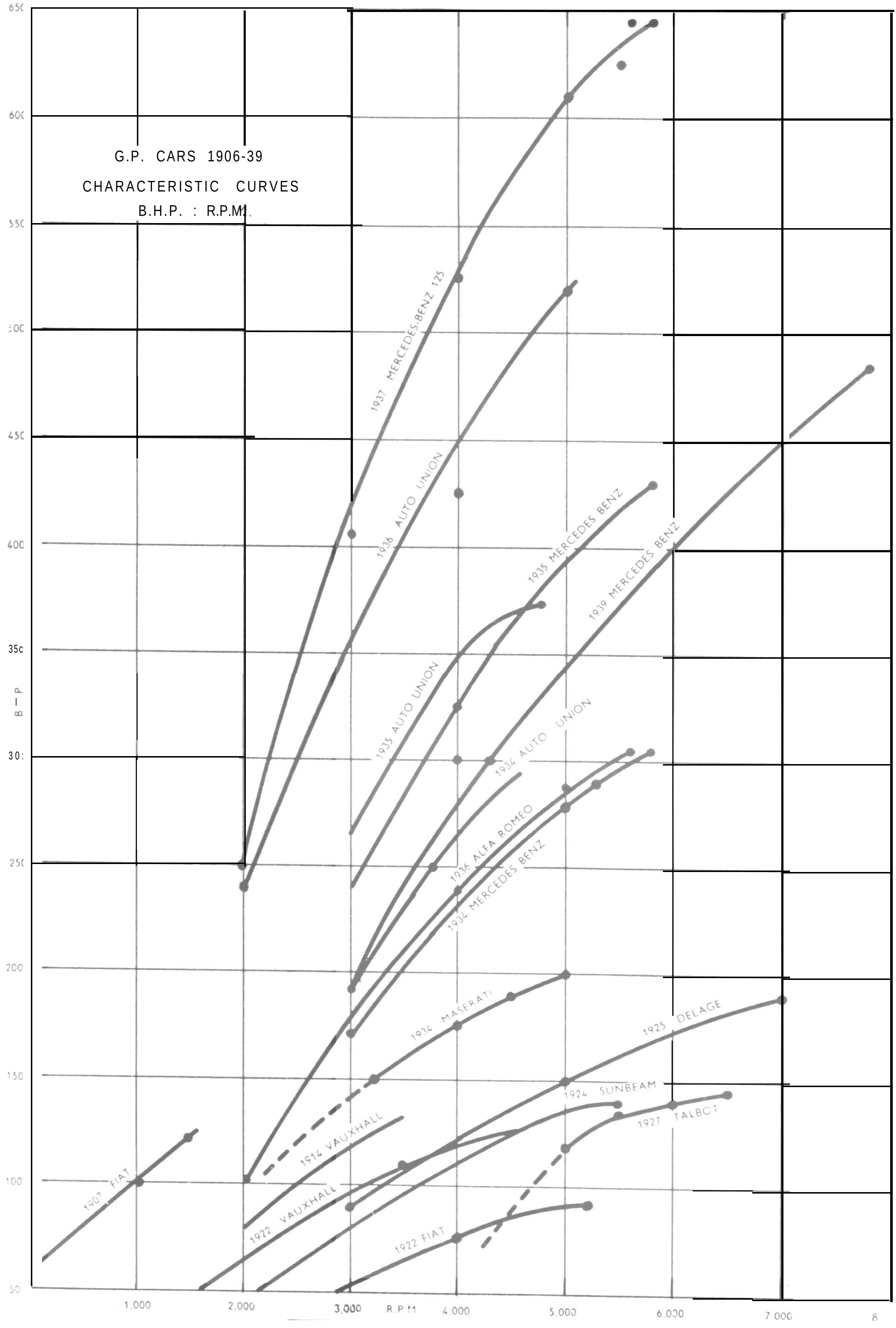
Whether it would be fair to assess a handicap in terms of lap speeds is a debatable point inasmuch as the older cars running on the equipment of the time would obviously lose a great deal of time in changing tyres. On the other hand, the latest types would find it difficult to put up an overall race speed which would compare closely with that achieved for the lap.

In the 1906 Grand Prix the overall average speed at the end of the first day was 8 per cent less than the record lap, but on the Rheims circuit in 1939 the difference was 10.2 per cent. In this respect the cars of the early '30's undoubtedly showed the great advantage, and in 1931, for example, Dreyfus lapped the Rheims circuit at 91 m.p.h. and finished the race at only 2½ per cent less than this. One may, therefore, predict that on the handicap proposed either Bugatti or the P3 Alfa Romeo would probably finish first.

A study of the individual allowances proves the very big difference made to the performance following the introduction of supercharging in 1923. The blown 2-litre Fiat car of that year gives away only 24 mins. to the 1921, 3-litre, Ballot, but receives over 20 mins. from the 1925 2-litre Delage, in which two years' experience of supercharging was combined with a twelve-cylinder power unit.

Later progress can be seen if we take as our pivot point the 1932 P3 Alfa Romeo Monoposto. We observe it can give the 1928 Type 35 Bugatti 94 mins. start, but it is in receipt of 12 mins. 30 secs. from a 1934 Auto Union. Incidentally the " theoretical " Rheims lap speed of the Alfa Romeo is 99.8 m.p.h. and the speed actually achieved in 1932 was 99.5 m.p.h. The actual speed put up at Rheims by the types 35B and 51 Bugatti in 1928 and 1931 were 91.4 and 92.78 m.p.h. which compare with 90.2 m.p.h. and 94.6 m.p.h. predicted, so that in three cases where the worth of the average index can be checked directly against recorded performance we find it to be accurate within 2 per cent.

It may clarify the detail development of average speed indices if the Py factor for the more important cars quoted throughout the text of this book are set out in tabular form as follows :



G.P. CARS 1906-39
CHARACTERISTIC CURVES
B.H.P. : R.P.M.
1937 MERCEDES-BENZ 125
1936 AUTO UNION
1935 MERCEDES BENZ
1939 MERCEDES BENZ
1935 AUTO UNION
1934 AUTO UNION
1936 ALFA ROMEO
1934 MERCEDES BENZ
1934 MASERATI
1925 DELAGE
1924 SUNBEAM
1927 TALBOT
1914 VAUXHALL
1922 VAUXHALL
1922 FIAT
1907 FIAT
B—P
R.P.M
1,000
2,000
3,000
4,000
5,000
6,000
7,000

Py FACTOR OF PRINCIPAL ROAD PRE-1939 RACING CARS

FIRST DECADE

Renault 100 Richard-Brasier 101.4	1906
Renault 100 Fiat 102	1907
Mercedes 105.5 Fiat 105.5	1908
Peugeot 107.5 Fiat 108	1912
Peugeot 109 Delage 110	1913
Mercedes 112 Peugeot 110.5	1914

SECOND DECADE

Ballot 118.5	1919
Ballot 115 Duesenberg 116 Fiat 117	1921
Fiat,111	1922
Sunbeam 114 Fiat 116	1923
Alfa Romeo 120 Sunbeam 121	1924
Delage 127.5 Alfa Romeo 127	1925
Bugatti 115.5	1926
Delage 129.2 Talbot 125.5	1927

THIRD DECADE

Bugatti 127	1928 and 1929
Maserati 133 Alfa Romeo 130	1930
Maserati 135.5 Alfa Romeo 132.5 Bugatti 132.5	1931
Alfa Romeo 140	1932
Maserati 139.3	1933
Mercedes-Benz 150 Auto Union 150 Bugatti 144.5 Alfa Romeo 143	1934
Mercedes-Benz 153 Auto Union 153 Alfa Romeo 149	1935
Auto Union 158 Alfa Romeo 153	1936
Mercedes-Benz 163.4 Auto Union 162 Alfa Romeo 155	1937
Mercedes-Benz 160	1938
Mercedes-Benz 165 Auto Union 162.5	1939

It will have been observed that in this chapter only ten makes are quoted to exemplify the development of the racing car over thirty-three years, with three national colours-France, Germany and Italy. Although both the United Kingdom and the U.S.A. can each claim to have won a Grand Prix, serious road racing has been almost solely confined to cars made in these three countries, and the regulations for the 1906 Automobile Club de France Grand Prix were, in fact, specially worded so that the existing supremacy of French cars (at that time made in larger quantities than those of any other nation) might be continued.

Of the first six Grands Prix only three were in fact won by French vehicles, Germany securing two wins and Italy one, but of the 28 major races held on both sides of the Atlantic in the ten years 1906-16, the national score was France 16, Italy 6, Germany 5. The French could, therefore, legitimately claim supremacy during this period.

During the ten years' racing between 1921 and 1930 German cars were largely prevented from competition (firstly by international and later by national regulations),

and of the 59 races listed in this book representing Grand Prix racing in this period the position was France 28, Italy 21, Germany 6. In the three racing seasons between the end of 1930 and the re-entry of the German cars under the 750 kg. formula of 1934 the Italians were dominant with twenty-two wins in thirty-two events, but in the six years immediately preceding the outbreak of war, the German Mercedes-Benz and Auto Union cars met the Nelsonic ideal " Not Victory but Annihilation," by winning fifty-two of sixty-five listed races and 83.5 per cent of the events in which they entered more than one car.

HANDICAP (BASED ON FASTEST LAP) FOR GRAND PRIX CARS 1906-39 OVER 500 KILOMETRES ON RHEIMS CIRCUIT

Year	*Engine Size*	*Make*	*Fastest Practice Lap*	*Starting Allowance*
1939	3-litre	Mercedes-Benz	117.5 m.p.h.	Scratch
1937	5.66-litre	Mercedes-Benz	116.3 ,,	1 min. 30 sec.
1936	6-litre	Auto Union	115.4 ,,	3 min.
1935	3.99-litre	Mercedes-Benz	109 ,,	12 min. 30 sec.
1934	4.36-litre	Auto Union	106.7 ,,	16 min.
1932	2.65-litre	Alfa Romeo	99.8 ,,	28 min. 30 sec.
1929	2.5-litre	Maserati	94.8 ,,	38 min.
1931	2-litre	Bugatti	94.6 ,,	39 min.
1927	1.5~litre	Delage	92.7 ,,	42 min. 30 sec.
1925	2-litre	Delage	90.4 ,,	47 min. 30 sec.
1928	2.3-litre	Bugatti	90.2 ,,	48 min.
1926-7	1.5-litre	Talbot	89.4 ,,	50 min.
1924	2-litre	Sunbeam	86.2 ,,	58 min.
I923	2-litre	Fiat	83.6 ,,	1 hr. 4 min.
1920-l	3-litre	Ballot	81.8 ,,	1 hr. 9 min.
1914	4.5-litre	Mercedes	79.8 ,,	1 hr. 15 min.
1922	2-litre	Fiat	79.2 ,,	1 hr. 17 min.
1913	5.6-litre	Peugeot	78.2 ,,	1 hr. 19 min.
1912	7.6-litre	Peugeot	76.7 ,,	1 hr. 24 min.
1908	12.8-litre	Mercedes	75.4 ,,	1 hr. 28 min.
1907	15.3-litre	Fiat	72.6 ,,	1 hr. 38 min.
1906	13-litre	Renault	71.2 ,,	1 hr. 45 min.

The number of makes which have appeared in Grand Prix racing contrasts vividly with the small number of national colours which they have carried.

Seventeen factories supported the 1908 Grand Prix, but only three were engaged at Rheims in 1939, and as we read entry lists bearing witness to the departed glories of Panhard, Mors and Clement-Bayard, and later, to the half-forgotten feats of Sunbeam and Peugeot ; as we recall the scarce-remembered victories of Fiat, Delage and Talbot, and relive the bitter realisation that Bugatti could no longer enter cars offering the hope of victory, the words of Chief Justice Crewe spring to mind :

> " And yet Time hath his revolutions : there must be a period and an end to all temporal things-*finis rerum*. An end of names and whatever is terrene and why not of De Vere ? For where is Bohun ? Where is Mowbray? Where is Mortimer ? Nay which is more and most of all, where is Plantagenet ? They are entombed in the urns and sepulchres of mortality."

To turn to statistics, it is relevant to note that of the twelve makers who ran cars in the first Grand Prix, only two, Fiat and Mercedes, had teams in the 1914 event. When Grand Prix racing was revived in 1921 only one firm, " S.T.D." had had previous experience in 1914, and of the names which appeared over the pits in 1921 at Le Mans, not one could be seen on the race programmes printed ten years later.

Obviously for most makers competition in Grand Prix events has been a transient experience so that the exceptions are all the more deserving of recognition. Jointly and severally the components of the Sunbeam-Talbot-Darracq group competed sporadically from 1906-39, and Fiat almost continuously from 1906-25. Delage first entered Grand Prix racing in 1913 and retired in 1927, whereas the Bugatti span both starts and finishes later, ranging as it does from 1922 up to 1938. Of the four companies actively engaged in 1939, Auto Unions were the junior with a first entry in 1934, Maserati having their initiation in this class of racing in 1929. Alfa Romeo secured a signal success by winning the first Grand Prix in which their cars were entered (1924 at Lyons). But no concern can match the record of Daimler Benz of Unterturkeim, for they played a prominent part in racing long before the type name " Mercedes " was coined for one of their 1901 models. This company, whose products were indubitably masters of the road in 1939, supplied the engine for the winner of the first race ever held-the Paris-Rouen event on the 22nd July, 1894, and were thus entitled to celebrate the fortieth anniversary of continuous participation in motor racing in the year in which Auto Union started their career. A history of Mercedes and Mercedes-Benz designs by themselves would indeed be a by no means inadequate summary of what had gone toward Grand Prix racing.

Taking the wider view, however, there has been no monopoly of success, the seeds of technical development have been fertilised by many minds of diverse nationality.

Analysis of 1939 design practice reveals that the de Dion rear axle, front wheel brakes and the use of spring dampers, together with twin overhead camshafts, inclined overhead valves and light alloy pistons had all been derived from French drawing-boards, the full-roller-bearing crankshaft and continuously engaged Roots blower had come from Italy ; the detachable wire wheel and the delivery of compressed fuel/air mixture from England ; the use of positive displacement blowers, both for supercharging itself and two-stage compression, from Germany. To the U.S.A. must be ascribed the origin of supercharging and of multi-stages, but German engineers made a direct contribution in the high tension magneto, welded steel cylinder construction, the welded steel tubular frame, torsion bar springs, hydraulic damping, and the practical application of independent front suspension.

CHAPTER TWENTY-TWO

The Development of The Grand Prix Car

1947-54

Those who have read thus far will by now be familiar with the theme that racing car performance depends primarily upon engine power, and the effective use of the power available, measured against the opposing drag and centrifugal forces. It should also be recognised that when an engine capacity limit is enforced a situation arises where, to quote from Chapter 7, " the designer who chooses the largest piston area, the shortest stroke and the highest r.p.m., has secured a fundamental advantage ". To this might be added that when supercharging is permitted there is the alternative of raising manifold pressure.

From the foregoing it follows that when racing-car designers began to contemplate the post-war scene, they found that if they decided to opt for the 1½-litre, supercharged engine, permitted under the regulations, they must concentrate upon securing maximum air flow by having the maximum possible r.p.m., or the highest boost pressure, or both. There was no existing experience of engines combining high r.p.m. and high manifold pressure, for Continental designers had concentrated on the former aspect and British engineers (who had produced the world's champion 1½-litre car in 1937) had specialised in high supercharge pressures.

As far back as 1934, the M.G. Company proved the benefits of using an efficient single-stage, Vane-type compressor, and they were followed by E.R.A., Ltd., who used pressures up to 45 lb. per sq. in. to obtain outputs of around 9 h.p. per sq. in. of piston area. Interpreted in terms of a 1939 six-cylinder power unit (bore and stroke of 63 by 80 mm.), this represented 260 b.h.p. at 7,500 r.p.m., and a b.m.e.p. of 304 lb. per sq. in. at 3,750 ft./min. On the Continent the 1939 examples of the Type 158 Alfa Romeo with a bore and stroke of 58 by 70 mm. were developing 225 b.h.p. at 7,500 r.p.m., or 260 lb. per sq. in. at 3,450 ft./min., using a single-stage Roots blower, and the V8 Mercedes-Benz, using two-stage Roots blowers, gave 270 b.h.p. at 7,800 r.p.m. ; the equivalent with a bore and stroke of 64 by 58 mm. of 300 b.m.e.p. at 3,000 ft./min.

Post-war practice in the realm of 1½-litre supercharged engines may be divided into three categories. The first, and ironically the most successful, class is made up of Alfa Romeo and Maserati who continued to develop pre-war designs of limited piston area. Alfa Romeos were almost unbeaten during the life of Formula I and they form an outstanding example of the importance of development in relation to design, the output in 1951 being 70 per cent greater than it was in 1939. This was done by increasing the absolute manifold pressure from approximately 2 ata. to over 3.5 ata. (i.e. by 80 per cent) which resulted in a 35 per cent increase in b.m.e.p., this being a vivid commentary on the inefficiency of the Roots-type blower for high boost pressures, even when it is compounded.

The economic limit of boost pressure for two stages with the Roots blower may be set at around 2.3 ata., but Alfa Romeo decided that the mechanical simplicity of the device, coupled with compactness and ease of installation, was worth a basic inefficiency which was reflected in the fuel consumption of barely 1½ m.p.g.

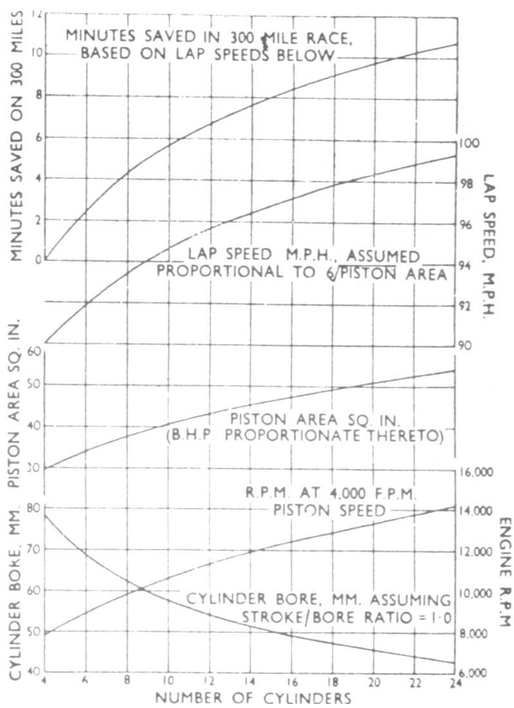
Simultaneously with raising manifold pressure Alfa Romeo increased the piston speed of their engines from 3,450 ft./min. up to 4,300 ft./min., and as much as 4,750 ft./min. was used for brief periods on special occasions.

These are probably the highest piston speeds which have successfully been used in racing engines, but the designers of new post-war power units adhered to the classic theme of raising crank speeds within a limit of 4,000 ft./min., by using short strokes and multiple cylinders. This was in accord with a trend of design flowing from the earliest days, and can be evaluated in terms of sq. in. of piston area per litre of engine displacement.

If a limit of 4,000 ft. per min. piston speed is assumed, it can be demonstrated that engine h.p. increases in proportion to the piston area, and within the limits of 1½-litre engine capacity the number of cylinders for any given piston area can be calculated if the stroke/bore ratio is known. If, for example, a ratio of unity is assumed, a four-cylinder with bore and stroke of 78 by 78 mm. will give 30 sq. in. of piston area and a twenty-four-cylinder with a bore of approximately 45 mm., some 55 sq. in., the maximum crankshaft speeds being just under 8,000 r.p.m. in the first case, and just over 14,000 r.p.m. in the second. Theoretically, the twenty-four-cylinder would be 10 per cent faster on a lap than the four-cylinder and would, therefore, win a 300-mile race run at modern speeds by over a quarter of an hour.

Expressed graphically, the long-term trend points to 35 sq. in. per litre in 1954, but, in fact, the predominant engine of Formula I had only eight cylinders and 21.8 sq. in. per litre ; the Formula II, 1953, four-cylinder Ferrari, 2-litre (90 by 78 mm.) had only 20 sq. in. per litre and of 1954, the eight-cylinder, 2½-litre Mercedes-Benz (76 by 68.8) 22.4 sq. in. per litre.

There are two explanations why this long-term trend was halted. One is that piston speed does not tell the whole story of engine stressing especially as related to piston rings. The well-known specialist in these components, J. L. Hepworth, has pointed out that if one takes an engine with proportions 76 by 114 mm., there is at 4,000 r.p.m. a mean piston speed of 3,000 ft./min. and a maximum piston acceleration of 41,000 ft./sec.^{2} (if the connecting rod has a length twice that of the stroke). If, however, stroke be reduced to 76 mm., the piston speed remains unchanged ; but if the crankshaft is raised to 6,000 r.p.m. the maximum piston acceleration will then rise by 40 per cent to 57,500 ft./sec.^{2} Developing this theme, it can be shown that whereas the piston speed of the four-cylinder Connaught is 3,937 ft./min. and that of the B.R.M. 3,800 ft./min., the piston accelerations are 81,300 ft./sec.^{2} and 154,000 ft./sec.^{2} respectively. Thus although it remains true that engines with geometrically



These curves show the relationship of 1½ litre engines with varying numbers of cylinders on a given circuit for lap speed and time over 300 miles.

proportionate cylinders of different size are identically stressed if their mean piston speed is the same, this does not hold good if they are geometrically disproportionate.

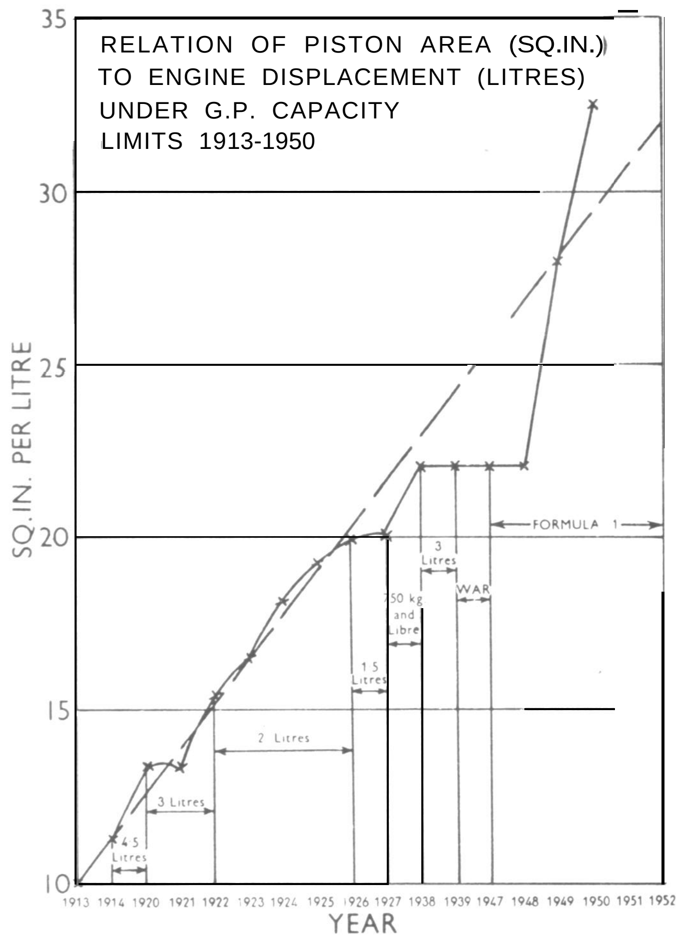
The practical consequence of this is that piston area can advantageously be increased by using large numbers of cylinders, but not by exaggerated bore/stroke ratios. Post-war experience has illustrated the practical limitations of the alternative concept of multi-cylinder engines and it may at this point be profitable to turn from these considerations of abstract engineering to some concrete examples of post-war practice.

If we start with the 1939 M.165 Mercedes-Benz engine for the W.165 car we observe from the cross-section that this V.8 was redolent of Unterturkheim practice. In particular one sees the welded-up steel cylinders, the exposure of the finned exhaust valve guide to water, the use of a drilled stem in the exhaust valve permitting sodium cooling and the characteristic all-roller-bearing crankshaft with split big ends. Particularly significant is the way in which the main bearing caps slide into the crankcase, the latter being tied into them with set bolts.

These engines were the first in the 1½-litre class to employ two-stage supercharging. Both blowers ran at engine speed x 1.25, the first stage with rotors 165 mm. long had a theoretical delivery of 2.15 litres, and the second with 95 mm. 1.25 litres. With an estimated volumetric efficiency of 85 per cent, we get a pressure rise of 9 lb. on the first stage and 12 lb. on the engine side of the second stage, giving a total of 21 lb. boost or 2.5 ata. In other words, on this engine the use of two-stage supercharging was determined by the desire to reduce power losses rather than to provide the highest possible pressures and corresponding maximum b.h.p.

The first wholly new post-war engine was the Arsenal-C.T.A., designed by Lory. This was also a V.8 and a comparison with the cross-section of the cylinder block of his 1927 Straight Eight Delage, reproduced on page 199, and with more detailed drawings of the engine given in Example No. 10, Volume I, support the theory that a man only designs one car in his lifetime.

The two four-cylinder blocks placed at the conventional included angle of 90 degrees were made in cast-iron with open water jackets



This curve shows the long term trend to increasing piston area per litre, but the latest practice conforms to the level of 1938-9.

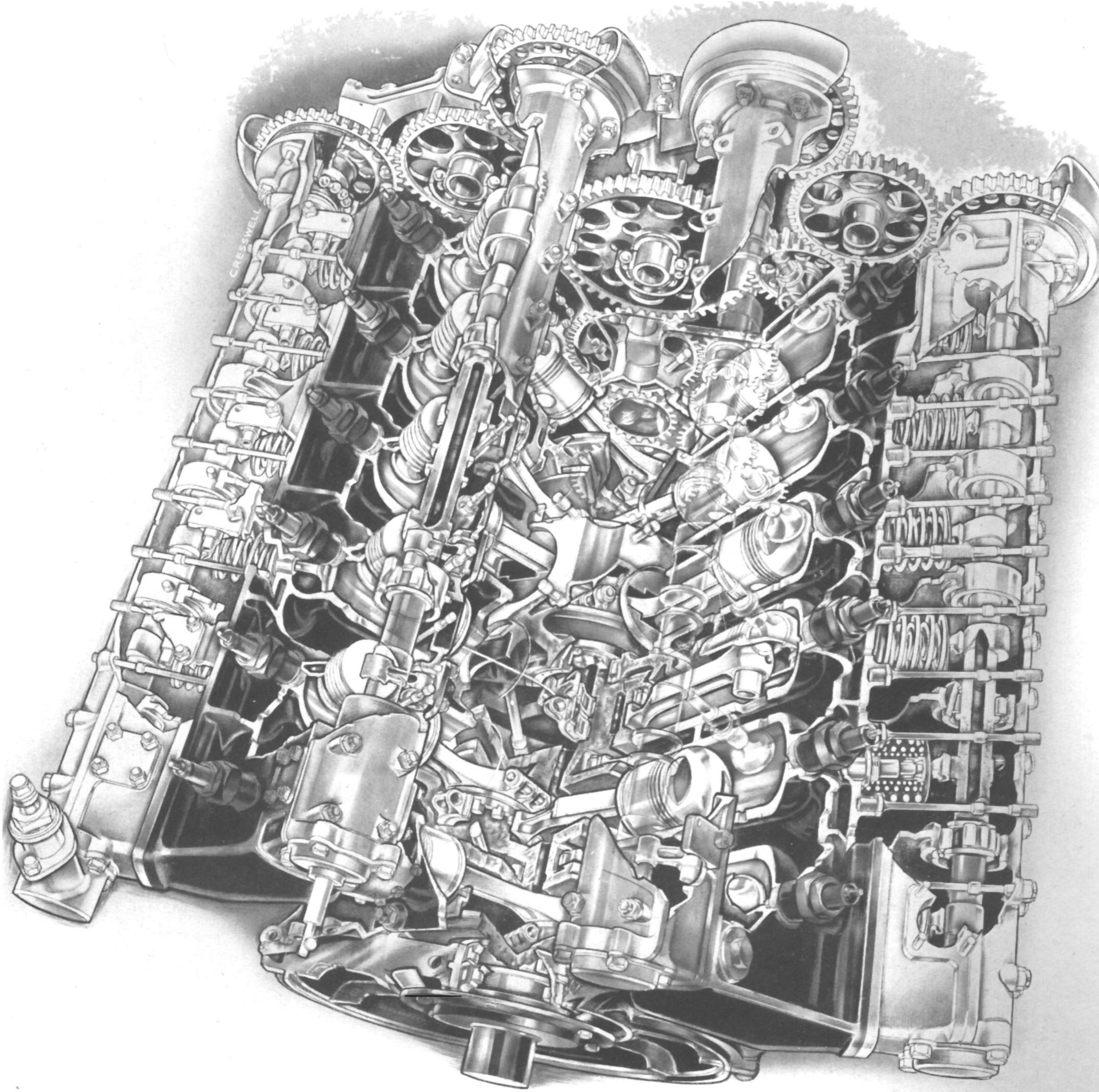
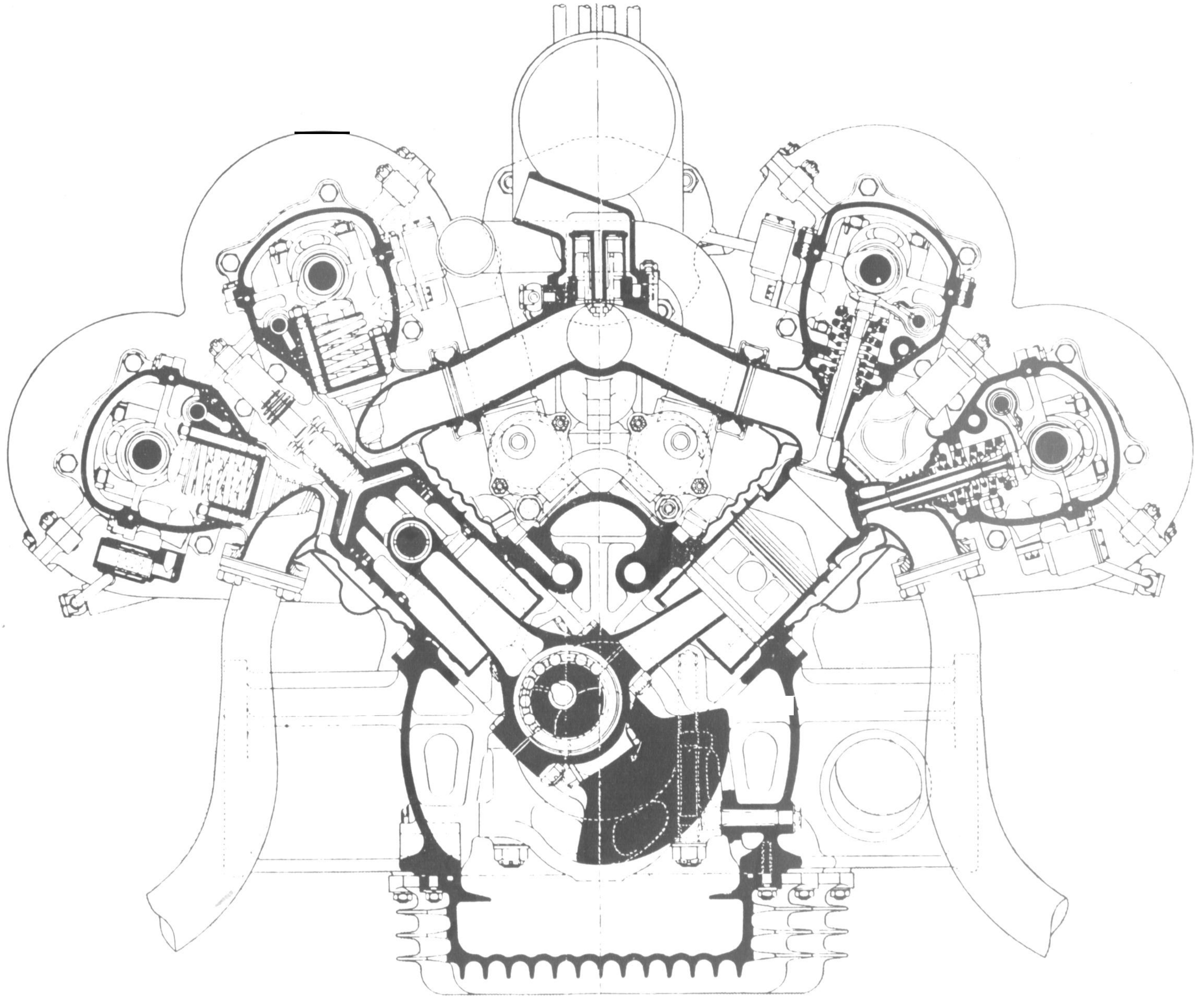
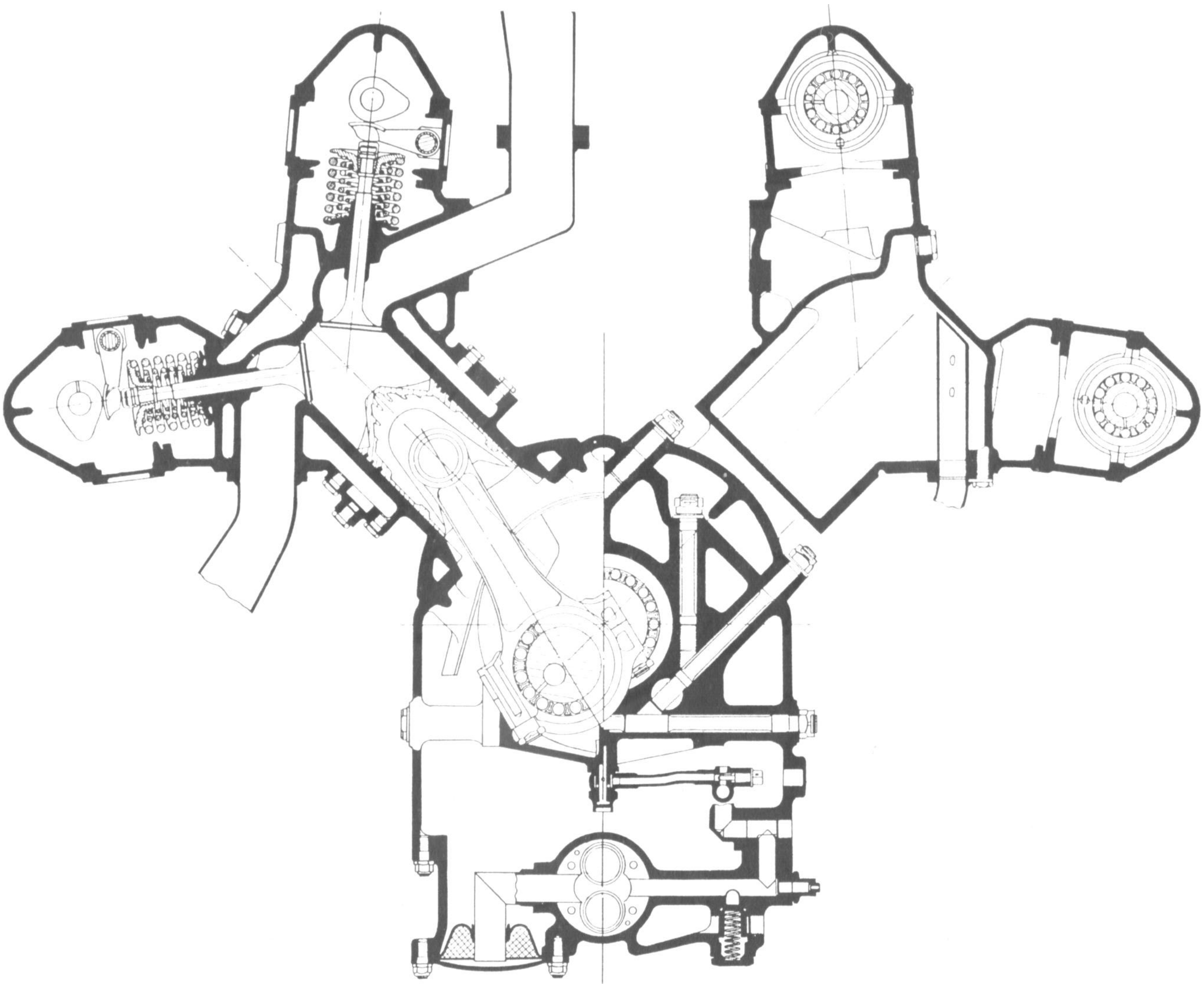


PLATE XXVI

All the complexity of the all-roller bearing V.12, double camshaft, 2-litre Delage enqine designed by Plancton in 1923, and modified by Lory in 1924, is to be seen in this Cresswell drawing.



The drawing (Scale 1 : 4) shows the leading features of the 1939 V.8 Mercedes-Benz 1½ litre engine which gave 270 b.h.p. at 7,500 r.p.m.



The 1947 Arsenal C.T.A. engine (a 1½ litre V.8) designed by Lory shows many features in common with his 1924-7 Delage engines.

THE ND IX

covered by plates. The two valves were inclined as before at an included angle of 100 degrees in the non-detachable (and, therefore, cast-iron) cylinder head. But, whereas the earlier engines had a single central sparking plug, on the later model two plugs were used off-set from the centre. Lory also used a full roller-bearing crankshaft assembly with split connecting rods, and as on the Mercedes-Benz the main bearings were tied in by transverse as well as by vertical bolts.

The two compounded Roots blowers were of equal size and ran at varying speeds with a rather higher boost than was provided on the German 1939 engine, and there was approximate equality in engine output and optimum crankshaft speed. As this engine never completed a lap in a Grand Prix we cannot estimate its effectiveness as a racing instrument, but one may suspect that the block and head construction would set a ceiling on maximum output on thermal grounds and from 1948 onwards 270 b.h.p. would have been inadequate.

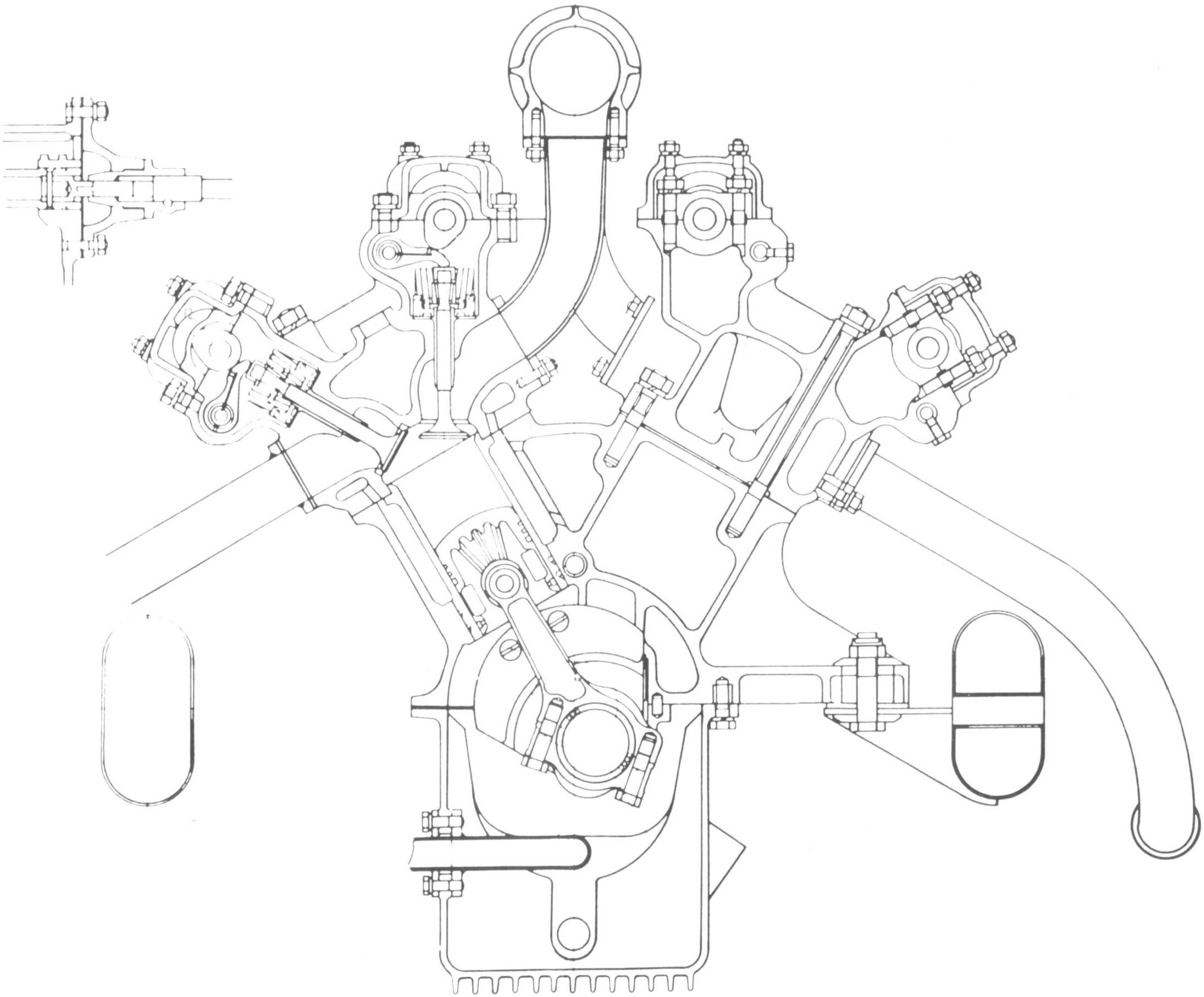
Even less can positively be said about the Flat 12, Porsche-designed, Cisitalia, but in view of the renown of the designers and the care and skill evidenced when the drawings are inspected, one must regret seriously that this engine was never developed. Amongst the many unique features was the use of single-stage Vane-type superchargers giving internal compression, and, as mentioned earlier, these form an efficient, if somewhat bulky means of supplying manifold pressure of 3 ata. or even more.

So far we have dealt only with precedents and projects, but when we turn to the Colombo-designed V. 12, two-stage supercharged, double overhead camshaft Ferrari, we are faced with an engine which achieved some success in a brief working life and which could doubtless have been developed much further if the constructors had not succumbed to the rival attraction of a 4½-litre unsupercharged power unit.

The cross-section of the Ferrari shows how the detachable cylinder liners are spigoted into the detachable light alloy head. The longitudinal section of the engine shows also the employment of hairpin-type valve springs, employed almost without exception in the world of racing motor cyclists but only by Ferrari and B.R.M. amongst Grand Prix cars.

With increasing engine speed and range of r.p.m., the valve gear problem grows obviously more difficult and it is sobering to reflect that at 10,000 r.p.m. each valve of a multi-cylinder engine will be lifted through about 0.4 in. and returned to its seat within a period of 0.005 seconds. The elimination of periodic valve spring surge over a wide range of r.p.m. is normally countered by the use of two, or perhaps three, coil springs lying one within another, but the alternative hairpin-type spring not only considerably reduces the mass to be moved but also gives great freedom from natural surge frequencies over a wide band of engine speed. It is not easy compactly to install the hairpin spring in a multi-cylinder engine, but this is the only disadvantage of the device.

The conjunction of a double camshaft cylinder head with two-stage supercharging gave the Ferrari an output of 305 b.h.p. at 7,500 r.p.m. which compares with 280 b.h.p. at the same crankshaft speed obtained on the single camshaft model, having otherwise identical constructional features and with single-stage boost. Both of these engines had the high piston area of 42.2 sq. in. (28 sq. in./litre) but even the more highly developed of them had the rather moderate output of 7.25 h.p. per sq. in, and 260 b.m.e.p.



The 1949 V.12 Ferrari engine was notable for using two camshafts and two stage supercharging. With dimensions 55 x 52.5 m.m.. it was of 1½ litres capacity, had detachable cylinder heads, wet cylinder liners, hairpin valve springs and gave 305 b.h.p. at 7,500 r.p.m.

That is to say, the fastest car competing in 1949 had basic engine performance factors lower than those attained in 1939.

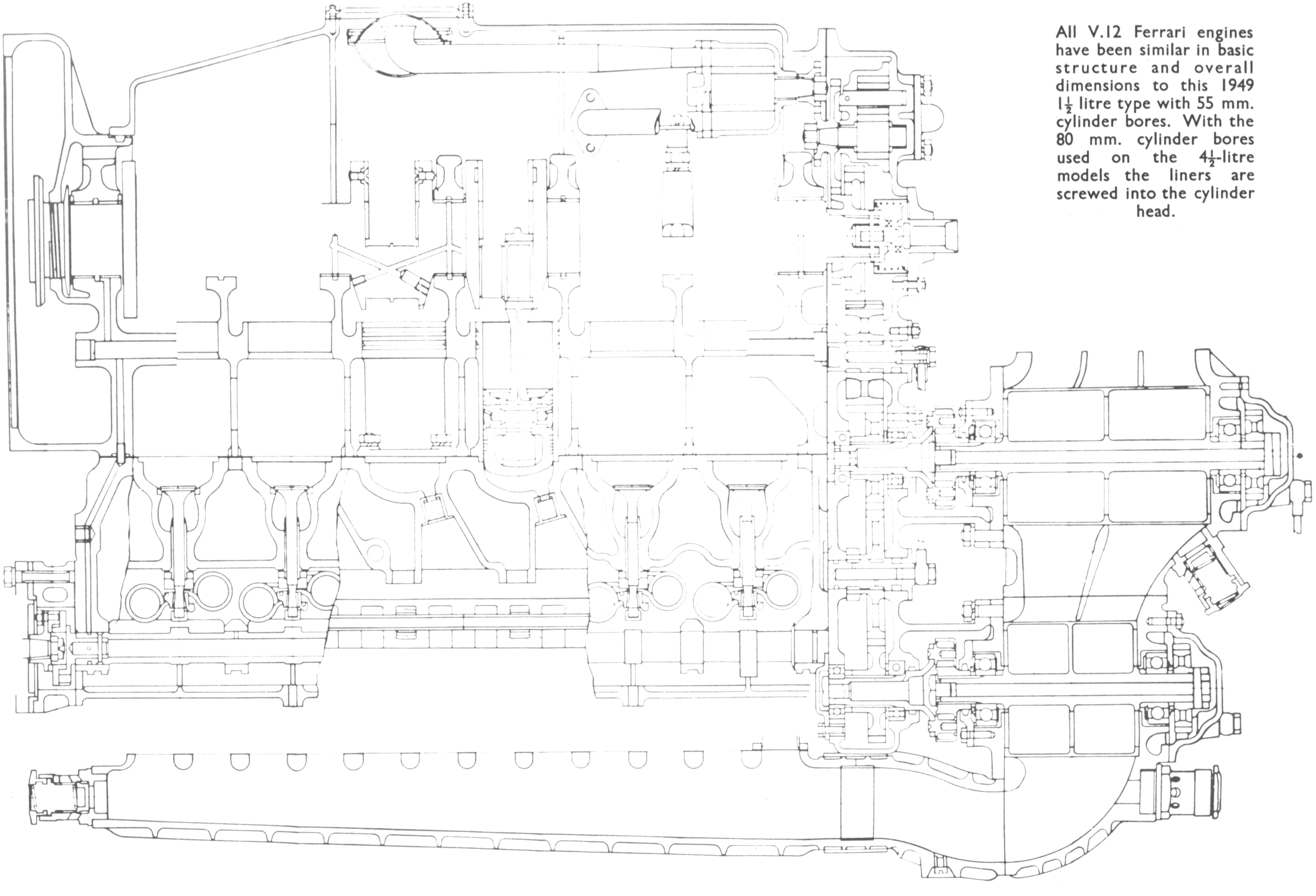
The British effort in the shape of the B.R.M. was far more ambitious. The basic proposal was to raise pre-war crankshaft speeds by 50 per cent and 1939 absolute manifold pressure by at least 35 per cent. Thus output per litre would be doubled, and gross power raised beyond the figure attained on the 1939 3-litre cars.

To achieve these ends it was imperative to have a piston area of some 50 sq. in. and a boost pressure of not less than 40 lb. per sq. in. The general layout of the engine and the type of blower used stems logically from these premises. To obtain the required piston area it was necessary to have at least twelve cylinders and the choice in fact made of sixteen cylinders was determined by two principal considerations. In the history of motor racing, straight-eight engines have been the dominant type, and although, from a constructional point of view, the B.R.M. may properly be regarded as two V.8's placed back to back, philosophically it is more correctly considered as two straight-eights face to face.

When starting with a clean sheet of paper in 1946 the B,R.M. designers probably thought that twelve cylinders went scarcely far enough along the lines of maximum piston area, whilst a l½-litre twenty-four-cylinder would have involved very formidable mechanical complications. Although the type was known in the aircraft world no such engine had ever been constructed for a racing car, whereas sixteen-cylinder engines were well-established. Both Bugatti and Maserati had constructed such power units (which followed upon the 1927 Fiat practice of coupling two in-line engines together) and the V.16 designed by Porsche for the Auto Union had been exceedingly successful in the 1934-7 period. Between 1938 and 1939 there was a good deal of discussion concerning V.16 3-litre engines and as recorded on earlier pages Alfa Romeo actually ran cars with engines of this kind in the Grand Prix racing of the time. In the technical press of the immediate pre-war period the merits of the 135 degree Vee angle were remarked upon. It was shown that such an arrangement reduced the bonnet height (and therefore the frontal area) and that it was possible to fit the engine into a frame of normal design and width.

Just prior to the war Sir Harry Ricardo was engaged by Alfa Romeo to design a 3-litre V.16 engine with this angle between the banks, and in his design the well-established Alfa Romeo practice of driving the superchargers and overhead camshafts through an ascending train of gears placed between crank throws numbers 4 and 5 was developed by adding a descending train coupled to a quill shaft giving limited angular movement and driving the clutch at half engine speed. This layout greatly mitigated the problems of running an eight-throw crankshaft over a wide range of r.p.m. without periodic vibrations, and provided the basic layout which the B.R.M. designers decided to follow.

The development of this line of thought resulted inevitably in a complicated engine that was heavy in relation to the swept volume ; but neither of these factors was of necessity a serious disadvantage. Looking back thirty years, we see that one of the most successful engines of the old 2-litre limit was the V.12 Delage, the complexity of which can best be appreciated from a study of Plate No. XXVI. Looking at the present, we see that the most successful engine is the straight-eight Mercedes-



All V.12 Ferrari engines have been similar in basic structure and overall dimensions to this 1949 1½ litre type with 55 mm. cylinder bores. With the 80 mm. cylinder bores used on the 4½-litre models the liners are screwed into the cylinder head.

Benz, which, in common with the B.R.M., has an offset propeller shaft drive with central gears and inclined cylinders arranged in two blocks of four.

But there is a big difference between the cylinder diameter of the two engines, and there can be no question that a design such as the B.R.M. which has cylinders of less than 2 in. diameter and inlet valve only 1.18 in. diameter is exceedingly sensitive to small changes in combustion chamber shape, port design and valve timing ; also that there are problems in maintaining the theoretical valve timing on an engine running at full power at, say, 11,000 r.p.m. which do not occur on a test rig at the same speed.

So far as weight is concerned it must be admitted that on the basis of lb. weight per litre, the B.R.M. scaling 340 lb. compared unfavourably with the V.12 4½-litre Ferrari with about 90 lb. per litre, the 2-litre Maserati with 165 lb. per litre, or even the 1922 Vauxhall 3-litre which weighed 250 lb/litre. Moreover, one may compare the 505 lb. total of the B.R.M. with the 442 lb. of the similarly sized Mercedes-Benz type W.165 of 1939. Whereas, however, the latter developed 270 b.h.p. and thus had a weight of 1.65 lb. per h.p. the 1951 B.R.M. weighed 1.2 lb./h.p. So on a power : weight ratio, the B.R.M. cannot be considered defective and, indeed, in fully-developed form, it has been one of the few engines fitted to a racing car which has developed more than 1 h.p. per lb. In view of these facts it may be asked why the B.R.M. has so negative a record in the GrandesEpreuves, and why in their single appearance abroad in a race of this category the performance of these cars recalled the words of Goldsmith : " Remote, unfriended, melancholy, slow."

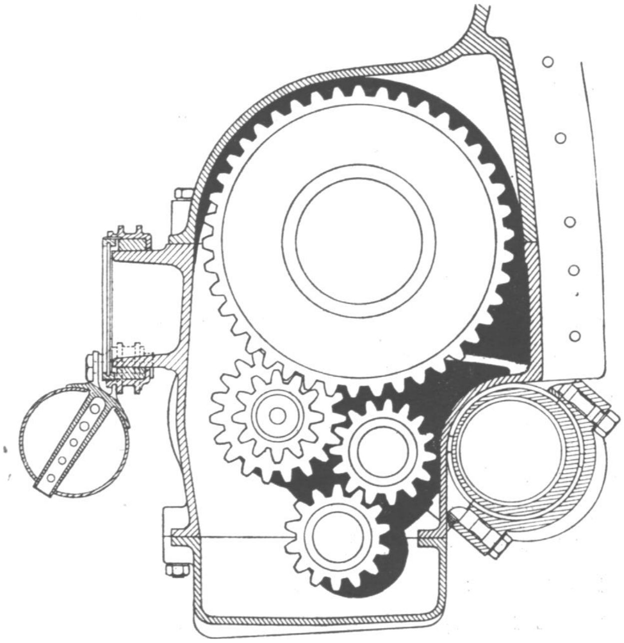
The answer lies in the disproportion between the means essential for the development of an engine of this kind and the financial and physical resources which were, in fact, available.

The gap, which would have been large enough in any case, was magnified by the choice of a centrifugal supercharger. The. merits of these components have been mentioned in the description of the car (Example 19) and some comments on the disabilities of the type have been set out in Chapter 12.

Here it was shown that the centrifugal type has by its very nature a boost curve which varies sharply with speed, and cars fitted with this type have been notoriously deficient in low speed torque. It was, however, thought in 1947 that the knowledge accumulated in aero engine work during the past decade would mitigate the disadvantages, so that adequate power could be secured in the low speed range coupled, with outstanding efficiency at peak speed.

In the long run these expectations were largely realised. In 1952-3 the B.R.M. engine had a mean effective pressure of 425 lb./sq. in. at 10,000 r.p.m., and the useful figure of 360 lb./sq. in. at 8,000 r.p.m., dropping back 310 lb./sq. in. at 7,000 r.p.m. But as run in the Formula 1 of 1950-1, with an earlier type of blower, giving a lower boost pressure, the figures obtained were far below those above quoted, being 345, 290 and 235 Ib./sq. in. at 10,000, 8,000 and 7,000 r.p.m. respectively.

Owing to the high crankshaft speed of the engine, it is difficult immediately to interpret these figures in terms of comparative road performance, but in Formula I (1950-l) form it can be shown that the surplus h.p. available for a B.R.M. driver on fifth gear was considerably lower than that of a Ferrari on fourth gear below 160 m.p.h. The benefit of the lower gears at lesser road speeds was limited by



In the post-war period, 1949-53, only B.R.M. and the 1954 Maserati designs have followed the Mercedes-Benz layout of 1938-9 in which (as shown here) the gear shafts were mounted transversely below the final drive.

the relatively narrow band of useful r.p.m., the ratio being about 1.33 : 1. Hence, to maintain effective performance it was necessary to engage fourth speed at 130 m.p.h., third at 110 m.p.h., second at 90 m.p.h., and first at 70 m.p.h. If, in consequence, the driver had to make ten extra gear changes in a five miles circuit, the time lost on this score alone would be not less than four seconds, or four minutes in the course of a race.

Unfortunately, another and perhaps even more serious penalty attached to the steeply rising torque curve. As shown in curves reproduced (*inter alia*) on pages 143, 147, 232 and 245, it has been normal to provide drivers with engines having a falling torque curve in the normally used range of engine speed. If wheel spin developed at, say, 100 m.p.h., and 6,000 r.p.m. on an indirect gear, there was some prospect that it would automatically die out with rising engine speed and with a constant throttle opening the tendency to spin would certainly not increase. Hence a small adjustment by the driver could restore stability. On the B.R.M., by contrast, if the engine speed rose from 7,000 to 9,000 r.p.m. the torque increased by 45 per cent, and in the absence of immediate and major action by the driver, control of the car was lost.

The development of maximum cornering power by the four-wheel drift (in which the driver keeps the rear wheels on the verge of spin) has contributed greatly to post-war circuit speeds and it was, therefore, especially unfortunate that owing to the characteristic of the B.R.M. power curve the drivers of these cars could make but little use of this valuable tactic.

Attack on these problems was delayed by the difficulties of machining and assembling the prototypes and during the effective life of Formula I the basic development thereof was delayed by a number of cracked cylinder liners and broken connecting rods ; troubles finally traced to water leaks at the cylinder head joint.

It should now be clear why the B.R.M. failed to challenge the pre-war designed Alfa Romeo before 1951, and it is but an academic satisfaction that it could have done so if it had been available in 1953 form.

The fact that the Ferrari successfully challenged Alfa Romeo with unsupercharged engine ran clean counter to theoretical expectation.

Before 1950 the battles in Formula I Grands Prix were fought between 4½-litre Lago Talbot cars with 63 sq. in. of piston area, which, being unsupercharged, had a manifold pressure of 1 ata. the l½-litre Maseratis with a piston area of 29.6 sq. in. supercharged at 2.6 ata. and the l½-litre Alfa Romeos with 32.8 sq. in. of piston area with a manifold pressure of 2.7 ata. From these facts we can assess the potential power of the engines by multiplying the figures together thus :

POTENTIAL POWER IN UNITS MEASURED BY PISTON AREA x MANIFOLD PRESSURE

Talbot — 63 (100) Maserati — 77.5 (123)

Alfa Romeo — 87.5 (139)

(The percentage figures are placed in parenthesis.)

On this basis the unsupercharged car was clearly at a considerable disadvantage and it proved generally inferior in speed in immediate post-war racing history.

The advent of the 4½-litre V.12 Ferrari in 1950 posed the question whether this inferiority was due inherently to the unsupercharged principle, or merely an accident caused by Mr. Tony Lago's decision to use a six-cylinder engine in his racing cars which had the same dimensions as those in regular production for use in touring cars.

Ferrari built only twelve-cylinder Formula I cars, and the 4½-litre version had a bore and stroke of 80 mm. by 74.5 mm., and a corresponding piston area of 93 sq. in., so that with 1 ata. manifold pressure it had a potential performance 47.5 per cent higher than the Talbot and 8 per cent ahead of the best existing supercharged power unit. It is, moreover, easy to envisage a sixteen-cylinder 4½-litre car with cylinder dimensions of 73 mm. by 67 mm. which would have a piston area of 104 sq. in., and therefore a performance potentially 65 per cent greater than the Lago Talbot and nearly 20 per cent ahead of the eight-cylinder supercharged Alfa Romeo.

In practice, Ferrari represented the high water mark of piston area for unblown Formula I engines, and correspondingly the B.R.M. had the largest piston area of the supercharged types—a fact which makes it all the more interesting to compare the interrelated aspects of cylinder capacity, piston area, and supercharge pressure.

The B.R.M. engine had sixteen cylinders, a bore and stroke of 49.53 mm. by 48.26 mm., giving it 47.8 sq. in. of piston area. Hence the potential performance should equal that of rival cars with manifold pressures as set out below :

MANIFOLD PRESSURE NEEDED ON B.R.M. TO GIVE EQUAL POWER TO COMPETING CARS

Competing Car	*Required B. R. M. manifold pressure*
Lago Talbot 4½-litre	1.32 ata.
Maserati l½-litre	1.62 ata.
Alfa Romeo l½-litre	1.83 ata.
Ferrari 4½-litre	1.93 ata.
Sixteen-cylinder 4½-litre	2.17 ata.

To put the matter in more general terms, the B.R.M. engine should be capable of equalling the power of a Lago Talbot on 5 lb. boost ; of a Maserati with 10 lb. boost ; a Ferrari with 15 lb. boost ; and an unblown 4½-litre engine with an equal number of cylinders with an 18 lb. boost. As the 1,100 c.c. version of the E.R.A. with Zoller supercharger won a 200-mile race at Donington using 40 lb. boost as long ago as 1937, it is apparent that the B.R.M. was not set any formidable task in equalling the maximum power of its rivals. It should, indeed, have been able to beat them by a very handsome margin.

To sum up, it was on fundamental grounds correct to choose a 1½-litre supercharged engine against a 4½-litre unsupercharged type as the ideal instrument for winning Formula I Grand Prix races but the unsupercharged engine offered very material benefits for any concern wishing to produce the best possible result within limited financial and physical means. It ran the length of a Grand Prix race on one tankful of fuel, and, taking into account time lost in stopping and restarting, this alone added at least a half per cent to the average speed. More important is the factor of reliability, for as engine volume is diminished and manifold pressures and crank speeds raised, so are engineering problems multiplied.

This is true even when enormous resources are available for development and research, as vividly shown by contrasting the racing record of the *circa* 6-litre, 10 lb. boost, 5,000 r.p.m., Mercedes and Auto Union cars of 1937 with their 3-litre, 25 lb. boost, 8,000 r.p.m. successors in 1938 and 1939. In the former year, of 71 cars jointly entered there were only eight retirements from mechanical trouble, a reliability factor of 89 per cent. In the ensuing two years there were 29 retirements out of 93 entrants, a reliability factor of only 69 per cent.

Nevertheless, reliability alone will not win races and just as the B.R.M. was a logical climax to the theory of Peter Berthon that power was best won by an engine of limited swept volume, high crankshaft speed, and high manifold pressure, so was the Ferrari the embodiment of opposing theory of Aurelio Lampredi that atmospheric inlet pressure could be offset by doubling piston area and trebling swept volume. As we have seen, this solution gave an engine that was approximately 100 lb. lighter than the B.R.M. and had more power at under 85 per cent of maximum crankshaft speed ; and these excellent results were attained with quite modest performance factors, the h.p. per sq. in. piston area being only 11 per cent higher than in the 1922 Vauxhall.

Turning now from a consideration of features specific to the individual make to a summary of details of common importance in Formula I cars, it must be recorded that a major change was the development of strip-type bearings which became almost universal in Formula II engines. From 1913 onwards ball or roller bearings were rightly considered *sine qua non* where the highest efficiency was needed regardless of constructional cost. During the period of World War II, and following upon experiments carried out as far back as 1934 in the U.S.A., plain bearings made from coated steel strip were developed to a high degree in aviation engines built in England. This in turn led to the introduction of this type of bearing by Vandervell to the Ferrari series of engines and even at crank speeds as high as 7,000 r.p.m. carefully controlled bench trials showed a clear gain in mechanical efficiency as compared with a roller and needle bearing assembly installed in an otherwise unchanged power unit.

As supplied by Vandervell, the bearing shells are made in halves formed out of a strip of steel 0.060 in. thick which is continuously coated to a depth of 0.010 in. by a layer of copper alloyed with 20-26 per cent lead and l-2 per cent tin. This copper/lead facing is in turn covered with a lead-indium overlay approximately 0.0015 in. thick, and although of such a very small dimension this coating, which actually contacts with the crankshaft, remains upon the bearing for the length of its life and plays a most important part in ensuring longevity and low friction losses.

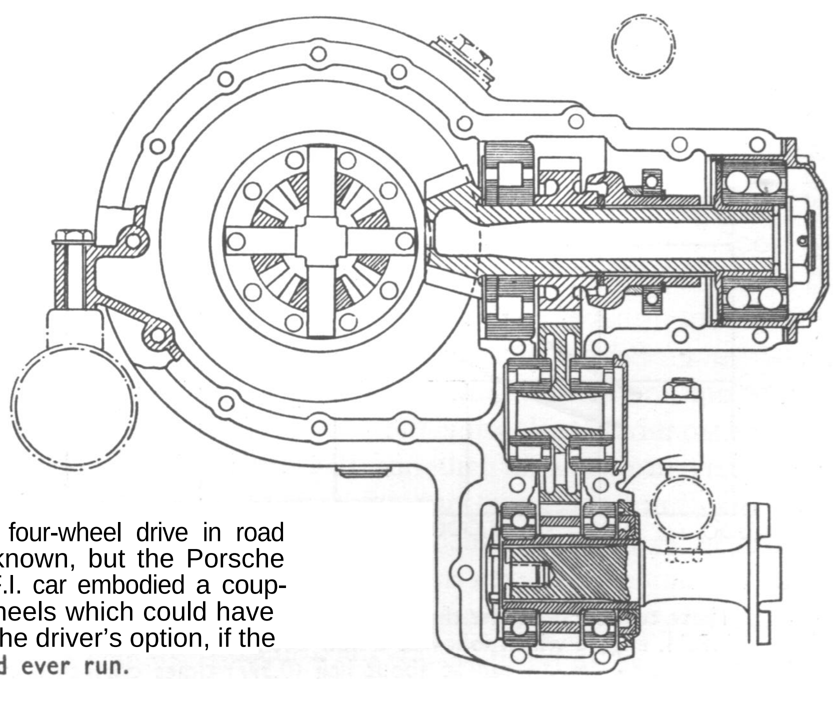
Similar bearings are supplied to the B.R.M., where they have proved equally successful at even higher crankshaft speeds, figures of over 10,000 r.p.m. having been attained.

Sparking plugs have been greatly improved, particularly in respect of being able to meet more widely varying conditions. World War II experience with aluminium oxide insulators showed that these had a mechanical strength and conductivity greatly superior to the traditionally established mica insulation. Following up work on plugs for highly supercharged British war-time aero engines, the Lodge Co. developed in the immediate post-war period a series of 14 mm. racing type plugs which showed a marked improvement on pre-war types, both in respect of their absolute endurance when running at very high b.m.e.p., as in the Alfa Romeo racing engines, and in ability to resist fouling by excessive oil or fuel.

The development of the unblown type of power unit was assisted by the construction of single carburetters embodying double (or triple) choke and jet assemblies which carburate the individual cylinders of a six-cylinder power unit with only three instruments. With a similar installation on a twelve-cylinder Vee-type engine, pairs of cylinders can be given equal mixture supply.

Only Cisitalia has followed the Auto Union practice of rear-engine mounting and B.R.M. have been the only concern to adopt the alternative Mercedes-Benz concept of a two-way inclined transmission line, described in detail in Example No. 17, Volume 1.

Both Alfa Romeo and Ferrari have used a central propeller shaft and combined gearbox and final drive aggregate mounted at the rear of the frame. This has raised the driver's seat and increased frontal area by comparison with the practice pioneered by the two pre-war German



The possibilities of four-wheel drive in road racing remain unknown, but the Porsche designed Cisitalia F.I. car embodied a coupling to the front wheels which could have been engaged at the driver's option, if the cars had ever run.

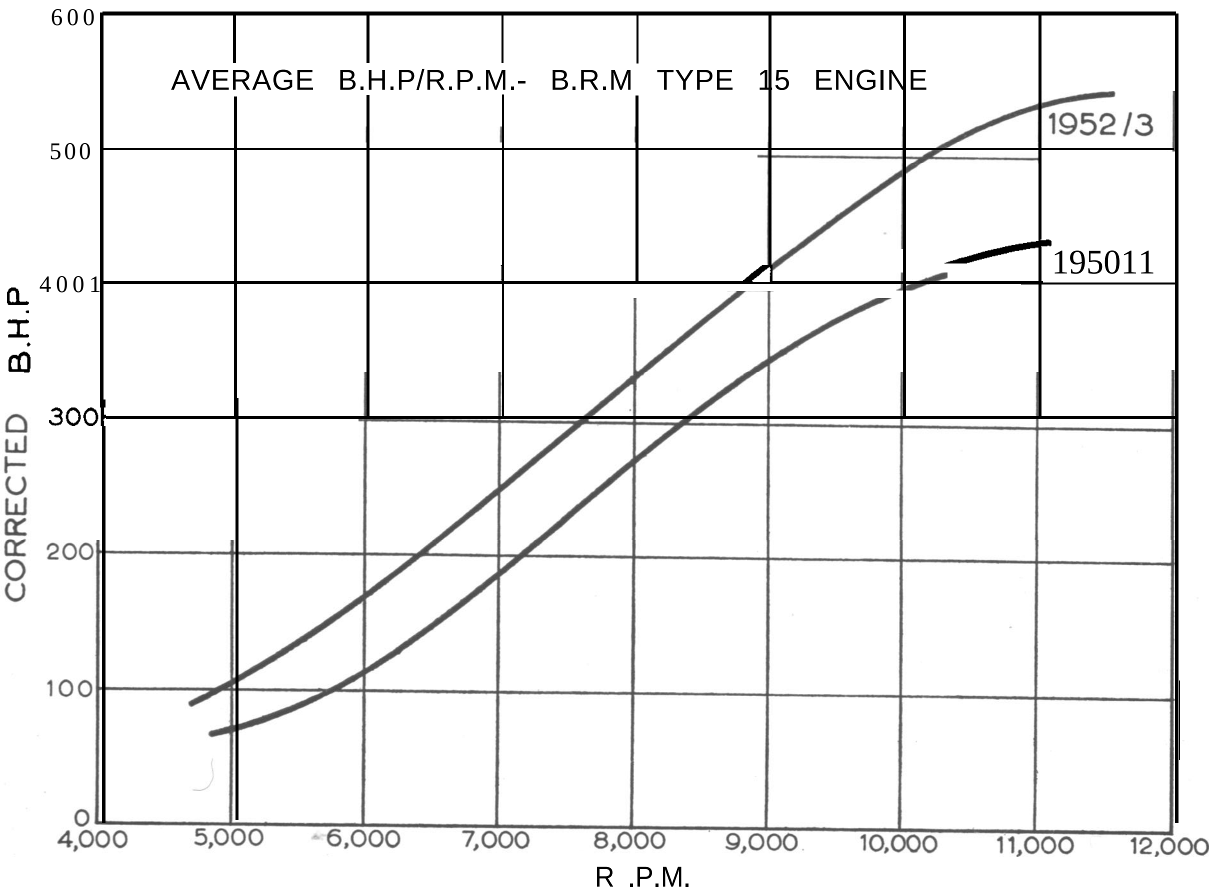
companies, but there has been a general feeling amongst drivers that both visibility and control were improved by a moderately high seating position.

With the exception of Cisitalia the de Dion type rear axle has become standard on most pre-1954 designed racing cars, and although Alfa Romeo continued through four seasons of racing with their original swing axle layout, they converted some of their cars to de Dion late in the 1951 season.

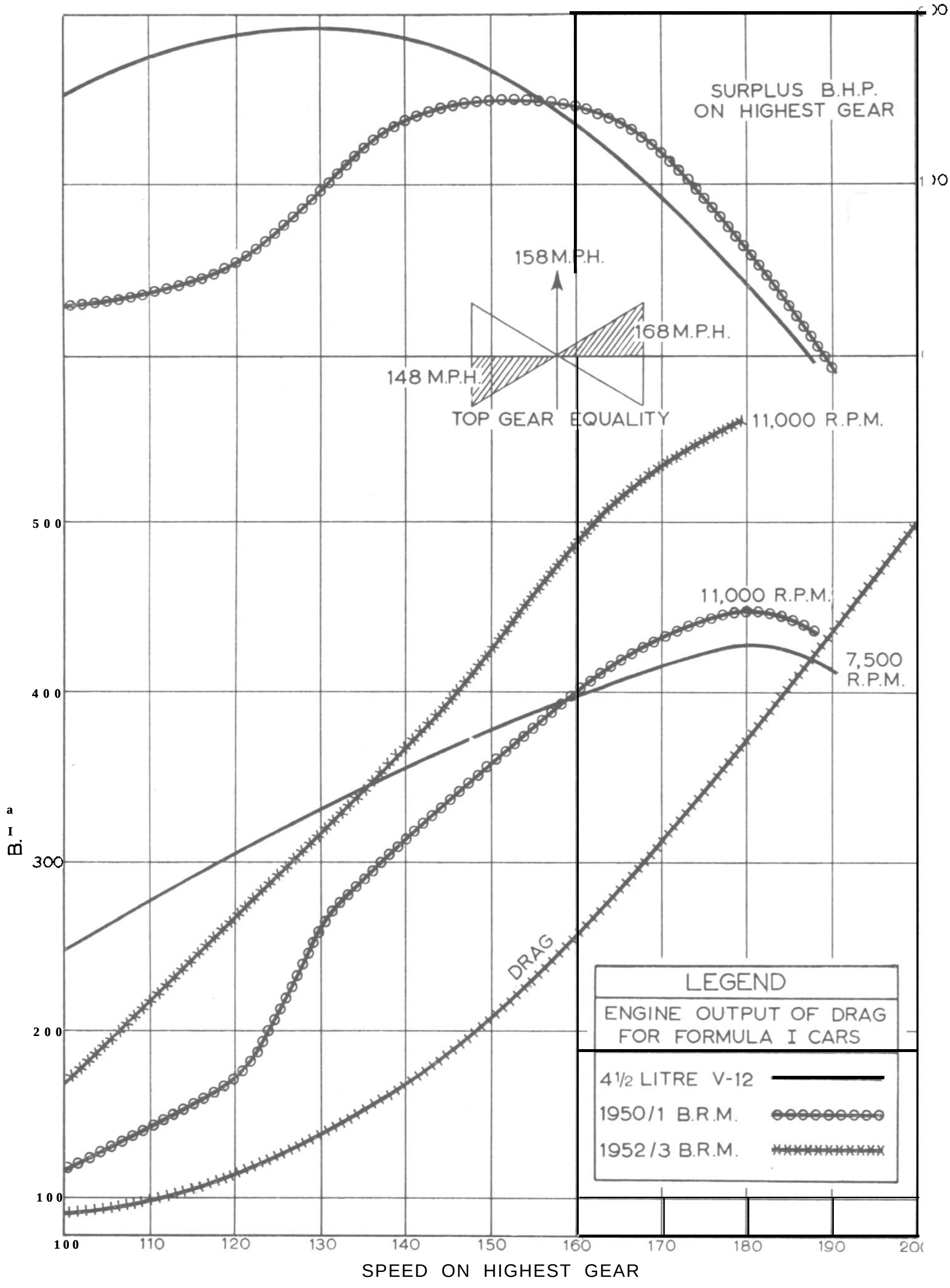
Swing axles give inherent over-steer for two principal reasons. The roll centre is very high, being determined by the intersection of lines drawn from the centre point of the tyre tread through pivot point on each swinging half axle. This in turn results in a large proportion of the over-turning moment being carried on the rear wheels, with a consequent deterioration in their joint cornering power.

Movement of the car on its suspension results momentarily in the rear wheels being heavily splayed out. This angle to the road also reduces their cornering power particularly if, simultaneously, centrifugal force is relieving the nearside tyre from its normal proportion of weight carrying.

From 1948 onwards Alfa Romeo mitigated these disadvantages by giving a marked dihedral to the half axles when the car was in a normal loaded condition. By thus ensuring that the rear wheels were inclined inwards (relative to the car) the cornering power thereof considered as a couple was augmented by perhaps 10 per cent.



These two curves show the big change in power output and torque characteristics on the B.R.M. engine which followed a new design of blower fitted after 1951. The clutch shaft ran at about half (0.597) times crankshaft speed.



The power available at the basis wheels on the 1950-1 and 1952-3 B.R.M. is here compared with a 4½ V.12 car at various road speeds in a gear giving comparable maximum speeds.

By reason of swing axle over-steer, aggravated by a particularly short wheelbase, the first Formula I Ferraris suffered from notably poor handling powers and the works resorted to lead ballast at the rear of the car to overcome this problem before embracing the de Dion system in the Formula II cars of 1949 and then in the unsupercharged Formula I cars of 1950 and subsequently. Other racing cars considered in this review have continued to use live rear axles despite the known disadvantages of unsprung weight and torque transfer.

During the life to date of Formula I, leaf springs were used throughout for the rear suspension systems with the sole exception of the Simca Gordini using links and

torsion bars, and the B.R.M. using the Lockheed air strut. The contribution of the latter to weight reduction has been put on record, but despite theoretical merits there is at the moment insufficient data to prove that it is superior as a suspension element *per se*. It is indeed somewhat remarkable that the two cars having the best road holding of all Formula I models (Alfa Romeo and Ferrari) used a single, and somewhat stiff, transverse leaf spring at both front and rear of their cars. The i.f.s. used by Alfa Romeo has been based on trailing arms, and by Ferrari on the more normal unequal length wishbone system, and these layouts are apparently regressive from a technical standpoint. One can only conclude that the ideal rate of suspension on a racing car has yet to be found and observe that the somewhat harshly sprung post-war models have had a considerably higher centre of gravity than the pre-war types. It is possible that given softer suspension their roadworthiness would have been adversely affected by roll.

Welded tubular frames of round or oval section have dominated post-war construction and nickel chrome molybdenum steel has been universally used for this purpose.

No comparison between pre- and post-war racing car performance is possible without drawing attention to the lower laden weight of the Formula I cars. Due to very high fuel consumption the Type 159 Alfa Romeo has gone to the start weighing 21.5 cwt., but the 4½-litre Ferrari has scaled less than a ton all-up so that it has had superiority in h.p./laden ton, the figures being approximately 386 h.p./ton for the unblown and 354 h.p./ton for the blown model. Neither factor falls far short of the 400 h.p./ton realised by the 1939 cars when carrying 75 gallons of fuel. But with not less than a 5 per cent reduction in h.p./laden ton, there has been a 10 per cent diminution of h.p./sq. ft., and it is in defiance of these facts that the post-war models have, at their peak, finished faster than the pre-war types on circuits having such differing characteristics as the Nürburg Ring and Rheims. As the brakes are in use for perhaps one hour out of the three hours taken for a 500 km. race, it is reasonable to suppose that changes in brake performance may affect race speeds by up to, say, 5 per cent. Brake linings having a better combination of fade resistance and stable, high, friction coefficient have become available in the post-war period and, as in the case of bearings and sparking plugs, it is interesting to record that England, which has made no effective contribution to Formula I racing in the shape of a complete motor car, has taken the lead in the production of a vital component. The Ferodo Co. has been prominent in this field and Dr. R. C. Parker, Technical Director of this company, has kindly contributed the following comments :

The very arduous conditions imposed on friction materials during the war years ensured that when Grand Prix racing recommenced greatly improved materials would be available. The years 1939-47 saw the development of a number of new Ferodo qualities, of which three were later to be submitted for Grand Prix events, viz. MR.41, MZ.41, and VG.95. Each of these materials offered a number of specific improvements over the pre-war materials, but this did not mean that the choice of lining for each car was automatic, for the characteristics of each vehicle had to be studied before the correct choice could be made. Indeed, in the period 1948-52 many further lining modifications were made to meet specific characteristics and although much of this work was based on the fundamental friction work that had its origin during the war years, research has been pursued with even greater vigour in the post-war period.

In the interest of logic, comments on the various brake linings required for the Grand Prix cars will be preceded by a brief description of the linings themselves. Developments since 1939 have followed along three independent channels : namely, the textile based quality, the rubber/resin moulded quality, and the resin moulded quality. All these three types were made prior to 1939, but it is only in recent years that their several functions have begun properly to be understood.

Typical of the three types are Ferodo MR.41 and MZ.41, Ferodo VG.95 and VG.97, and the Ferodo DM range. The fade resistance of these linings increases in the above order, as does a number of their important physical properties such as hardness, elasticity and so forth. Their order of durability cannot be so clearly stated since this value depends very precisely upon the operating conditions and the availability of three basic types, each with their own variations, does not represent pandering to arbitrary fashion, but is dictated by necessity.

The magnitude of the friction level need not be dealt with at length as a lining may be made with any required friction level within the range now accepted by the majority of brake manufacturers. Indeed, this aspect is rapidly becoming one of the minor problems in brake lining design and what is needed can readily be given. Thus the Alfa Romeo with a two-leading shoe brake uses a lower friction material, though of the same type, than that used on the Simca Gordini and Talbot with their single-leading shoe brakes. Again, the Maserati with the two-leading shoe front brakes and the single-leading rear brakes have employed two qualities of differing friction level.

The biggest factor affecting the choice of a lining for racing has been the cooling and the design of the brake drum. Some post-war touring cars have had brakes extremely prone to heat spotting, while complaints of front end judder at high speeds have been frequent. Both of these vices have been present to a lesser degree in many Grand Prix cars. A study of the brake drums used on Grand Prix cars shows they all have one thing in common, i.e. they all employ a bimetallic system consisting of a light alloy housing and an alloy cast-iron or cast-steel liner. The biggest difference has been the amount of cooling employed and an examination of the photographs of the frontal views of the Alfa Romeo, Ferrari and Talbot cars, for example, will show that the exposure of the front brake drums to the air decreases in the above order. It has also been noticeable that the Alfa Romeo 158s have had less braking troubles than the Ferraris, and the Ferraris less than the Talbots. It is perhaps signtficant to recall that on the 1938 Mercedes Type W.163 which had front brake drums well concealed by the tyres, it was found necessary to replace the orthodox peripheral finning by a type of centrifugal fan that not only caused air to flow over the drum surface, but also extracted air from within the brake drum. Not unconnected with the cooling problem is the fact that the Maserati and OSCA cars have had little or no braking trouble since the shoes were made wider on the later models.

The relatively low temperature developed on the Alfa Romeo Type 158-9 has enabled it to run successfully on textile linings, and in their championship year (1951) Ferodo MZ.41 was used throughout. The softer properties of the textile lining, and hence its high ratio of real to apparent area of contact, has not caused any trouble with heat spotting, drum distortion, or judder. It is of particular interest to note that in the previous years Alfa Romeo ran on MR, and to cope with the higher speeds they shortened the lining on the trailing shoe. Although this device was not primarily introduced for this purpose, it increased the ratio of the apparent to the real area of contact and so minimised localised

high temperatures on the drum at the expense of heavy pedal pressure. The use of MR.41 quality enabled the same advantages to be retained but with a normal pedal load.

*The zinc wire quality, MZ.41, was used on the OSCA, but on the 4 CLT Maserati with its two-leading and single shoes it was found that VG.95 on the leading shoes and MZ.41 on the trailing shoes was a good combination.Indeed, this choice gave them a compromise between good jade resistance, good wear, and resistance to drum spotting. One Maserati also appeared with wider two-leading shoes all round, and this had a satis-*factory brake performance with MZ.41.*

The 4½-litre Talbot was alone among Grand Prix cars to use a dry mix/resin quality. This type of material was required to give the fade resistance necessary in view of the relatively poor cooling, although heat spotting and judder did occur. The rubber/resin moulded type of lining with its even greater heat resistance could not be used on this car without inducing an unacceptable intensity of‘ heat spotting.It may be remarked, in passing, that the use of wider shoes and re-positioning of the brake farther into the cooling air would have enabled the Talbot to employ a textile quality. Alternatively, the use of a brake drum less liable to heat spotting would have enabled VG.95 to be used.

The excursion of the H. W.M. in post-war Grand Prix Formula II events is note-worthy, and some mention of its brake system is desirable. These cars used VG.95 on two-leading shoe Girling brakes against Al-fin brake drums. The braking performance was consistently successful, with no fade and no heat spotting.

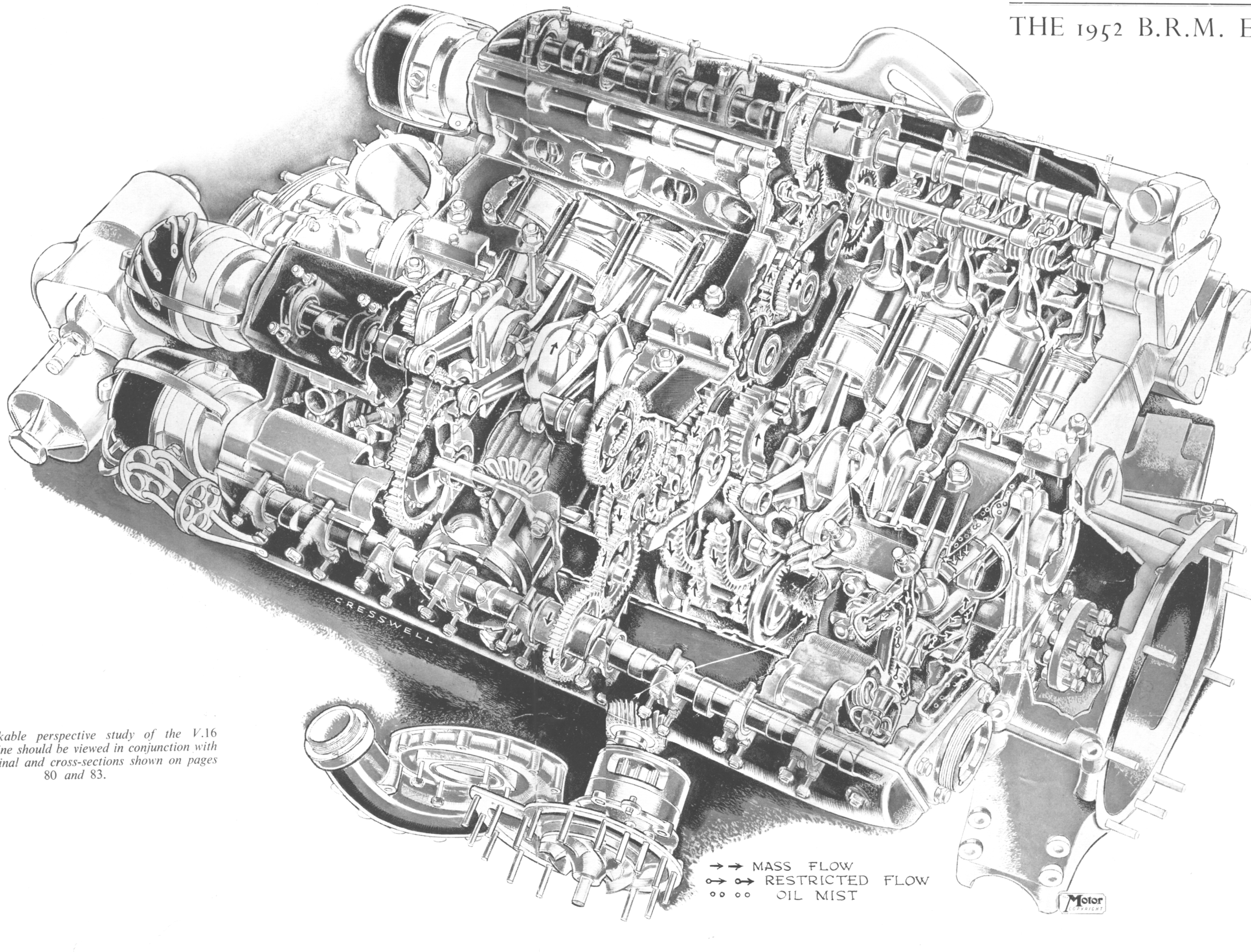
The B.R.M. in 1951 was alone in its use of the Girling three-shoe brake. Fitted with VG.95 the brakes exhibited excellent fade resistance and resistance to judder. The latter might be attributed in part to the more uniform stresses imposed by the three equally spaced shoes.

It is clear that each Grand Prix car has its own individual braking problems, and that the improvements accomplished were due in part to improved design of brake lining material, and in part to a better understanding of the role played by the brake shoes, the brake lining, and the brake drum. It is stimulating to note that considerable improvements in brakes may yet be attained, a task to which the brake lining manufacturer, brake designer, brake drum manufacturer, and chassis engineer must all contribute in harmony and considerable measure.

Corresponding with these improvements in lining materials a good deal of work has been done in the improvement of the brake drums themselves. The Al-fin system of chemically bonding a ferrous liner into a light alloy drum has resulted in a much closer union of the two metals than was possible by any pressed or shrunk-in method with corresponding improvement in heat transfer. A further trend has been towards markedly greater width of drum, whilst the use of transverse fins on the periphery designed to act as air extractors and used by Mercedes-Benz in 1939 has been followed by drums having ducts cast into the face to achieve the same end. First used by Maserati in 1949, this arrangement was adopted during 1951 by Ferrari.

It seems likely that brake materials and brake design will change radically in the future as a consequence of the general use of disc brakes. These are already to be seen on the 1952 version of the B.R.M. and in this Girling layout small diameter friction pads are pressed caliper-like upon a disc by hydraulic means. Experimental work shows that whereas not more than 2 h.p./sq. in. of brake lining area can safely be imposed with a normal layout, as much as 14 h.p./sq. in. can be

THE 1952 B.R.M. ENGINE



This remarkable perspective study of the V.16 B.R.M. engine should be viewed in conjunction with the longitudinal and cross-sections shown on pages 80 and 83.

extracted from Mintex friction material with a disc brake. As there is also a considerable saving in unsprung weight, and as the problems of relative expansion no longer exist, the success of this development would seem to be assured.

With reduced gross h.p. and lower all-up weight the problems confronting tyre engineers were considerably less in the post-war period than they were in the three racing seasons immediately precedent thereto. Advantage of this has been taken progressively to reduce rim and overall diameters so that the 19 in. driving wheel carrying a 7 in. tyre of 1939 has given way in many cases to 17 in. rims carrying the same section with a resulting combined saving in weight for wheel and tyre together of 69 lb. or about 10 per cent.

An experiment by Ferrari in reducing rim size even further to 16 in. was unsuccessful and led to their loss of the 1951 Spanish Grand Prix and the World Championship.

To sum up. The development of Formula I racing cars during 1947-51 has in the main followed previously tried and proven lines, but this has not prevented an increase in performance which was marked during the first four years and spectacular during the season of 1951.

A distinguishing feature of Formula II cars has been an apparent regression to four- and six-cylinder power units ; types which have not been seen for thirty years.

The desire on the part of relatively small companies to build low cost, easily maintained, engines was one of the reasons for this phenomena, but there are also technical advantages to record. Reference has already been made to the use of jet and choke assemblies individual to each inlet port. Such an installation increases power by reducing restriction in the inlet system, and, more important, offers the opportunity of obtaining a ram effect. By adjusting the length of the inlet tract to the length of the exhaust pipe, it is possible to induce waves which can result in positive pressure ducting the inlet cycle.

It is obviously easier to develop and maintain a four- or six-port inlet system on these lines than it would be with eight or twelve cylinders, and the mean effective pressure on the four-cylinder 2-litre Ferrari was 14 per cent higher than on the V.12 of the same engine capacity.

Generally speaking, the Formula II cars showed no great technical advance over their immediate predecessors, but there was a general trend to the multi-tube frame and the merits of the de Dion axle were confirmed. No novelties were to be seen in power units, but the advantages of using two sparking plants in cylinder bores of more than 75 mm. diameter were found to be most marked when using high domed pistons which almost bisected the combustion chamber.

The performance of the Formula II engine compared with the previous designs of the same capacity can be tabulated thus :

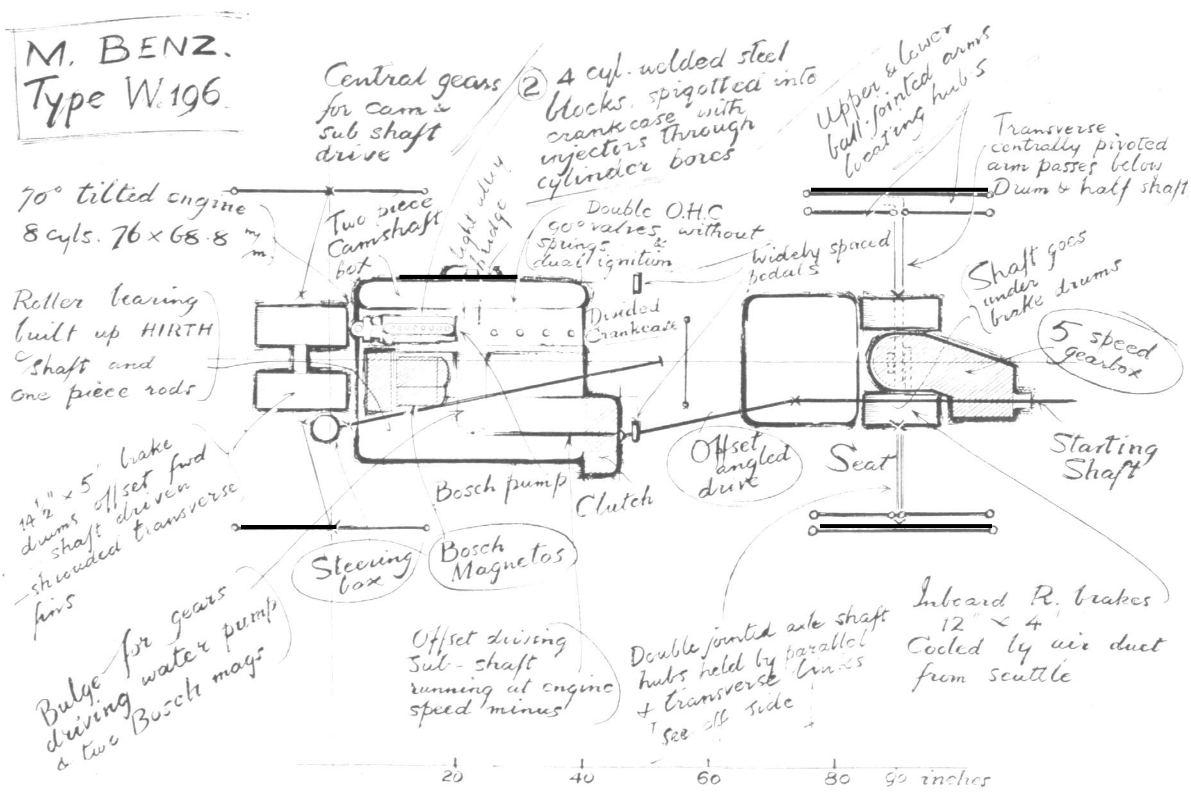
PROPORTIONS AND POWER OF UNBLOWN ENGINES 1922-1954

Car	*Cyls.*	*Bore*	*Stroke*	*Piston Area*	*b.m.e.p.*	*r.p.m.*	*f.p.m.*	*b.h.p.*
1922 Sunbeam . .	4	68	136	23.8	127	4,250	3,640	83
1924 Delage	12	51.3	80	38.4	130	6,000	3,150	120
1949 Ferrari	12	60	58.8	52.5	145	7,000	2,700	155
1953 Ferrari	4	90	78	39.5	165	7,000	3,800	180
1954 Mercedes-Benz . .	8	76	68.8	56.2	172	8,500	3,950	280

It has been recorded on earlier pages that the road speed of the 1953 cars was little inferior to the 1951 Formula I models. In 1954 we have witnessed the breaking of a number of absolute records by the Mercedes-Benz W.196 designed for the new 2.5-litre formula. These cars have created a sensation by the originality of their engine and chassis design, and by the bold introduction of aerodynamic bodies with fully-enclosed wheels, which have been used despite a weight penalty of 60 lb., and the openly expressed preference of the drivers for a view of the front wheels on the road. The company has produced alternative open wheel models so that the best choice can be made for any given circuit, but the chassis is common to both types of body.

It is not yet possible fully to describe this model but some general notes show that it opens up a new era in the design of the Grand Prix car.

The W.196 with 90 in. wheelbase and enveloping body weighs 1,540 lb. (13.8 cwt.) and the frame is constructed from tubes of either 25 mm. or 20 mm. (1 in. and 0.8 in.) with a wall thickness of 1 mm. or 0.04 in. Two large-diameter cross-tubes are placed just behind the plane of the front hubs, and the steering box, steering connections and mountings for the engine and front brakes are located on them. The front brakes have two leading shoes and light-alloy drums with an overall diameter of 14½ in. They have transverse fins, partially shrouded to increase air flow over the face of the drum, and they rotate on bearings fixed to the frame. The centres of these brakes are mounted slightly forward of the wheel centres and the connection between the two is through the medium of open halfshafts each with two universal joints. The radiator is mounted very low down at the extreme front of the tubular structure with a header tank placed



The unique general arrangement of the principal components of the 1954 Mercedes-Benz Type W196. is shown in this annotated sketch.

immediately above the brake drums. The front brakes have a shoe width of approximately 3½ in. and a drum width of nearly 5 in., the rear brakes being somewhat narrower, about 12 in. diameter, and placed on each side of the gearbox-bevel box aggregate so that all the brakes of the car are placed inboard and represent sprung weight. It is worth noting that although the 1922-3 Benz six-cylinder 2-litre racing cars had inboard brake drums at the back and the 1926 Alvis 1½-litre cars inboard drums at the front (with front wheel drive) this is the first time that such a system has been used in a Grand Prix car, although a similar layout was adopted by Lancia with their Mille Miglia and Pan American sports/racing cars in 1953.

The front suspension of the W.196 is of conventional wishbone design with all parts machined from the solid as is traditional Unterturkheim practice, exemplified as long ago as 1914 by the construction of one-piece crown wheels and halfshafts on the Lyons Grand Prix cars, there being a total of fifty such units prepared for the team.

This apparent lavish expenditure of material and man-hours is determined by the belief that anything which will secure reliability by eliminating the risk of welding or riveting is worth while.

The engine is mounted with the cylinder axes at 70 degrees immediately behind the front brake drums, and is a most interesting blend of old and new engineering practice. A choice of eight cylinders in line has caused considerable comment in view of the world-wide trend to the V.8 configuration, and the considerable experience obtained with this type by Mercedes-Benz with their W.165 1½-litre model of 1939. A 2½-litre unsupercharged V.8 was, in fact, projected for the new formula, but rejected whilst in the paper stage on the grounds of excessive weight, largely caused by the duplication of the auxiliary drives. Having decided not to use four cylinders face to face, as it were, it was decided to adopt the alternative of placing them back to back so that although the cylinders are in line they are in two blocks of four separated by a train of gears which drives the camshafts within one-piece valve covers with further gearwheels driving a subshaft which would conventionally lie beneath the crankshaft, but which does in physical fact lie beside it.

The cylinder construction has the bores and combustion chambers made in one piece from steel forgings and welded together in groups of four, with the ports welded in on top of the hemisphere and subsequently surrounded by a welded-on steel-sheet water jacket. This arrangement has been used on all Mercedes-Benz racing cars since 1914, but the new engine has two valves per cylinder inclined at 90 degrees in place of the normally used four valves at an included angle of 60 degrees, and, most remarkable of all, the valve gear does not include valve springs. On two previous occasions the Mercedes-Benz racing department has tried to eliminate these components which on a high r.p.m. engine take up a lot of space better devoted to other purposes if they are to be reasonably reliable. In their place a return cam is used to bring the valve very close to the seating, gas pressure being relied upon to effect the final seal. This does not end the novelty of the engine design, which includes direct fuel injection using components similar to those standardised on the catalogue 300 SL model. Whereas, however, on the sports car injection is made into the combustion chamber, on the racing car with far higher explosion pressures and temperatures the nozzle is shrouded by being placed in the cylinder bore so that it is masked by the piston at the moment of ignition.

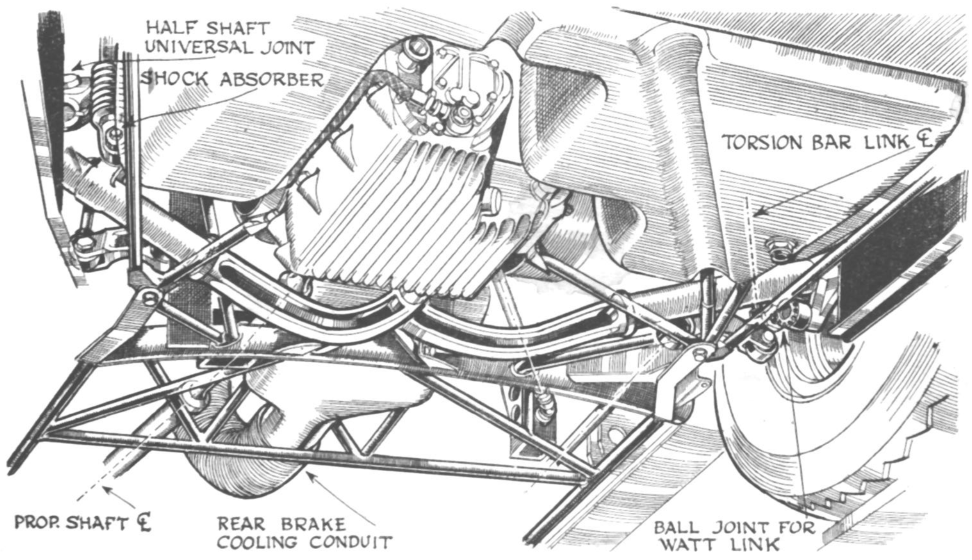
Air is supplied to the inlet ports through a large-diameter pipe, the absolute pressure of the ingoing air being determined by a throttle placed ahead of the front cross-member through which the pipe passes. This must be the only car in which the throttle assembly is fixed to the frame.

The Stuttgart engineering staff are no strangers to fuel injection, and a project for such an installation on their pre-war V.12, 3-litre, supercharged power unit has been mentioned in Example 17, Volume I. So also has the use of the straight-eight layout, for the Mercedes-Benz racing engines of 1924 and 1934-7 were so constructed. These all had one-piece crankshafts running on roller bearings with split big ends for the connecting rods with split cages for the rollers. The W.196 reverses this practice, having one-piece connecting rods and a built-up Hirth-type crankshaft.

Assuming that the problems of a springless valve gear would not have been tackled unless maximum crankshaft speed of about 10,000 is envisaged, and that a revolution range of 5,000 r.p.m. was required, difficulties present themselves in respect of crankshaft torsional vibrations, but these are virtually eliminated by the use of central driving gears to a subshaft which drives the clutch at rather less than crankshaft speed.

Using drawings of past Mercedes-Benz engines as a guide, it is possible to make an approximate scale drawing of the power unit, and its situation within the frame, and this shows how the clutch itself is set well to the left-hand side of the car, power being then taken through a two-piece propeller shaft, the second section of which passes beneath the inboard rear brake drums and enters the five-speed all-indirect gearbox which is placed behind the rear axle centres. It will be noted that the engine is started by a shaft which engages with an extension of the gearbox, there being obvious difficulties in threading a starting shaft through the inboard brake mechanism at the front end of the car.

Power is transmitted from the gearbox through a limited-slip differential to halfshafts with double universal joints, and the hubs are located by a unique system of links.



The rear-axle layout of the Mercedes-Benz, Type W. 196, is of great interest for it is of modified swing axle type. As shown here each open halfshaft has two joints and the hubs are located by pivoted arms giving a low rear roll centre.

It is a matter of exceptional interest that Mercedes-Benz abandoned the de Dion axle for their 1954 new cars. In its place they located the rear wheels transversely by two single arms which pivot on the centre line of the car (and therefore have a longer effective radius than a simple swing axle) and also around a plane about 6 in. from the ground, this exceptionally low centre providing a corresponding reduction of rear roll couple. These swing arms are not subject to bending moment, for the hubs are located fore and aft by two rods of equal length, one of which is placed above the wheel centre and runs backwards, and the other below the wheel centre and runs forward. It is a characteristic of this survival of James Watt's ingenuity that the resultant travel of the hub centre is vertical, but the wheel is, of course, subject to changes in camber angle, which are accommodated by ball joints. A separate arm with a rubber bush is used to link up with the longitudinal torsion bars and a direct-acting hydraulic damper.

Similar elements are used at the front end of the car and the rate of the springs is such as to provide much softer suspension than has been seen on any other post-war racing car, with the possible exception of the G-type E.R.A.

It has been found that the streamlined shape gives better than usual stability in cross-winds. The underpart of the car is unbroken except for the base of the gearbox, and the overall form has been developed at the Stuttgart Forschungs-institut für Kraftfahrwesen und Fahrzeugmotoren, in a wind tunnel which is sufficiently large to accommodate complete cars with wind speeds of 150 m.p.h.

It seems appropriate to end this chapter, and to close this book, with this description, even in broad terms, of one of the fastest road racing cars the world has yet seen, constructed by the makers of the first successful petrol-propelled vehicles which the world saw.

As he surveys the span between these events it is the writer's hope that this book will serve a useful purpose in acting as a guide to the engineering aspects of racing car design, and as an *aide memoire* to the development thereof over the past fifty years. He ventures also to suggest that to engineers and enthusiasts knowledge of the past may be of some service in predicting the future, and to conclude with the advice given to his students by Sir John Soane : " We must not only be intimately acquainted with what the ancients have done, but endeavour to learn from their works what they would have done. We shall thereby become Artists, not mere Copyists ; we shall avoid servile imitation and, what is equally dangerous, improper application."

PLATE XXVIII

BEFORE BORDEAUX. — "By 1903, performances had increased to the point where Gabriel averaged 65.3 m.p.h. over 342 miles between Paris and Bordeaux, and, although the roads were liberally policed, spectators were permitted to stand on the edge of the road over the entire racing distance"

Here Gabriel is seen just before finishing and winning the last great Town to Town Race.

PLATE XXIX

FAST GOING.--" Against these adverse,factors in early racing may be set the comparative absence of corners in relation to the total circuit length. This was particularly marked in the case of the 1906 Grand Prix, for after having covered six miles from the stands, the drivers turned left round the 130 degree bend, and then set off down the straight. Apart from a slight kink in the village of Ardenay, this straight certainly deserved the name, for the cars could be held flat out for the ensuing twenty-one miles!"

Here is Gabriel on a De Dietrich flat out on a straight of rather lesser length on the 1906 Ardennes Circuit.

PLATE XXIX

HARD LABOUR. — " It was general practice to stop at the replenishment depot every lap and make good the tyres which had been changed during the preceding circuit, and as many as four spares were carried by some of the cars. From all this it will be seen that the riding mechanic's job was no sinecure."

Carl Joerns and his mechanic stop for a left-hand rear tyre change in the 1908 A.C.F. Grand Prix ; a Renault passes them.

Plate XXXI

HEROIC POSE. — " With the rise of professional skill it was natural that the professional virtuoso should come upon the scene . . . Georges Boillot, an employee of Peugeot, made himself the idol of the crowd before the 1914-8 war, and he achieved his position not only by his skill at the wheel, but also by his undoubted gift of capturing the imagination of the public."

Here Boillot is seen just after winning the 1910 Sicilian Cup.

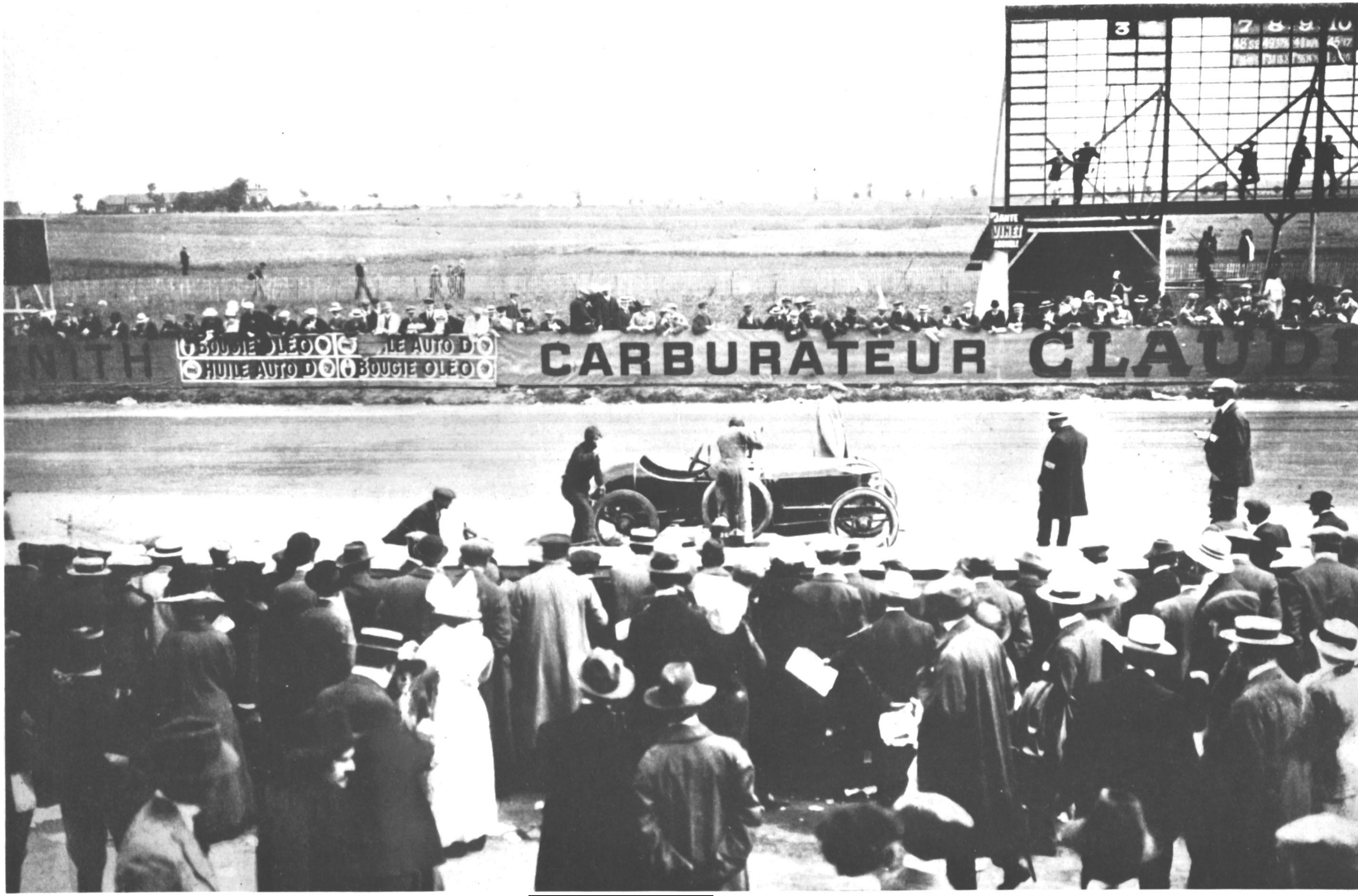


PLATE XXXII

COMING OF AGE.--" Aesthetically, as well as mechanically, the 1912 Grand Prix at Dieppe was a dividing point, for whereas the big cars, exemplified by Peugeot and Fiat, retained the earlier tradition, the 3-litre models, as typified by Sizaire-Naudin, Sunbeam and Vauxhall, had pleasingly proportioned bodies giving full protection to the occupants."

A.J. Hancock replenishes the 3-litre Vauxhall at the pits in the 1912 A.C.F. Grand Prix after completing three laps of the 48-mile circuit.

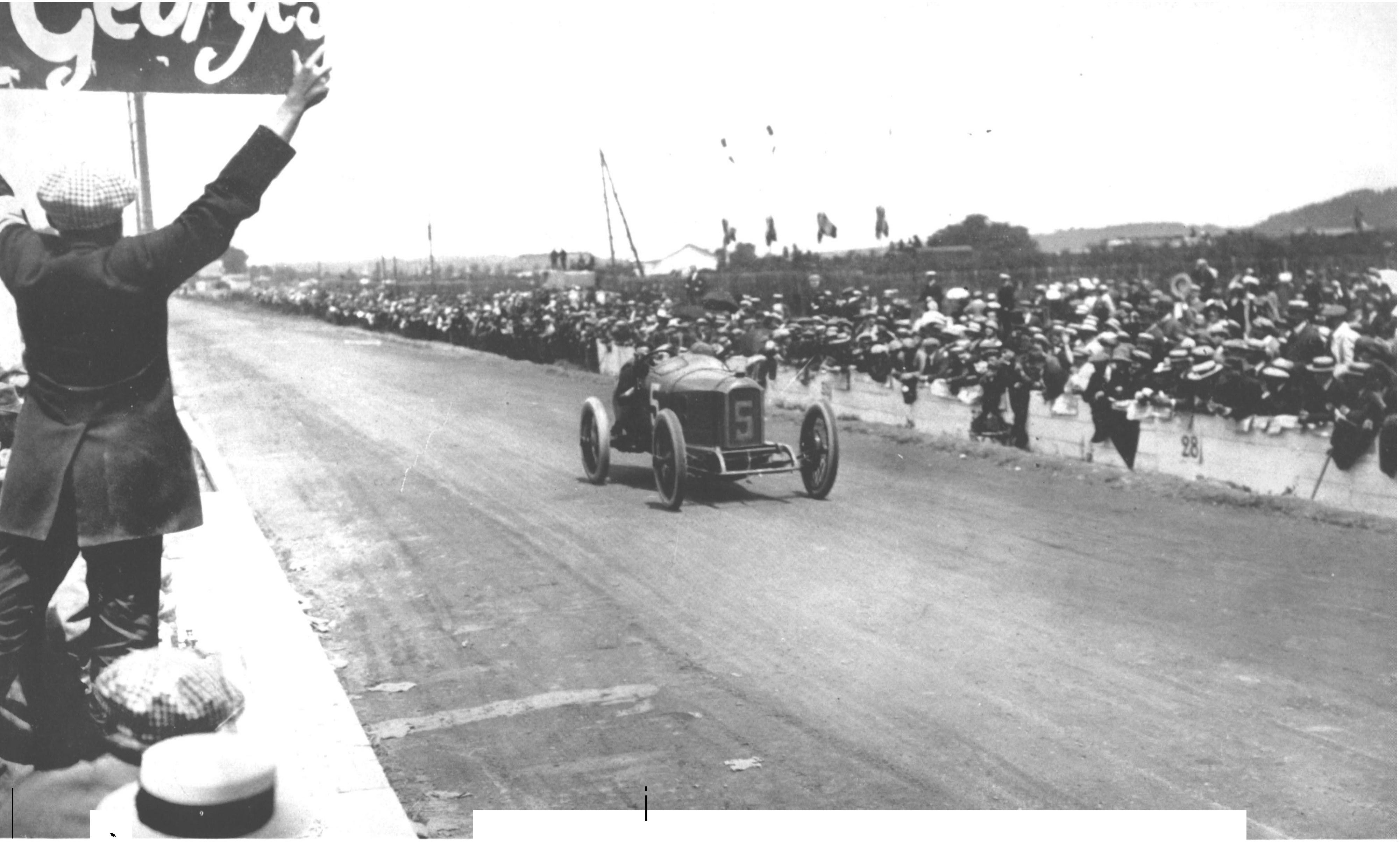


PLATE XXXIII

HEROIC DEFEAT. — " Boillot had left the line five and a half minutes before his pursuer, Lautenschlager. Thus, although he lost the lead on the eighteenth lap, this fact could not be signalled to him until, having completed the nineteenth circuit, he passed the pits on his way to the last round, in which after six and a half hours of desperate struggle he broke up his engine when only fifteen miles, from the finish, and was not ashamed to weep. "

The Peugeot pit reverses a signal to inform No. 5 that with one lap to go in the 1914 Grand Prix the position is " 2ème Georges ".

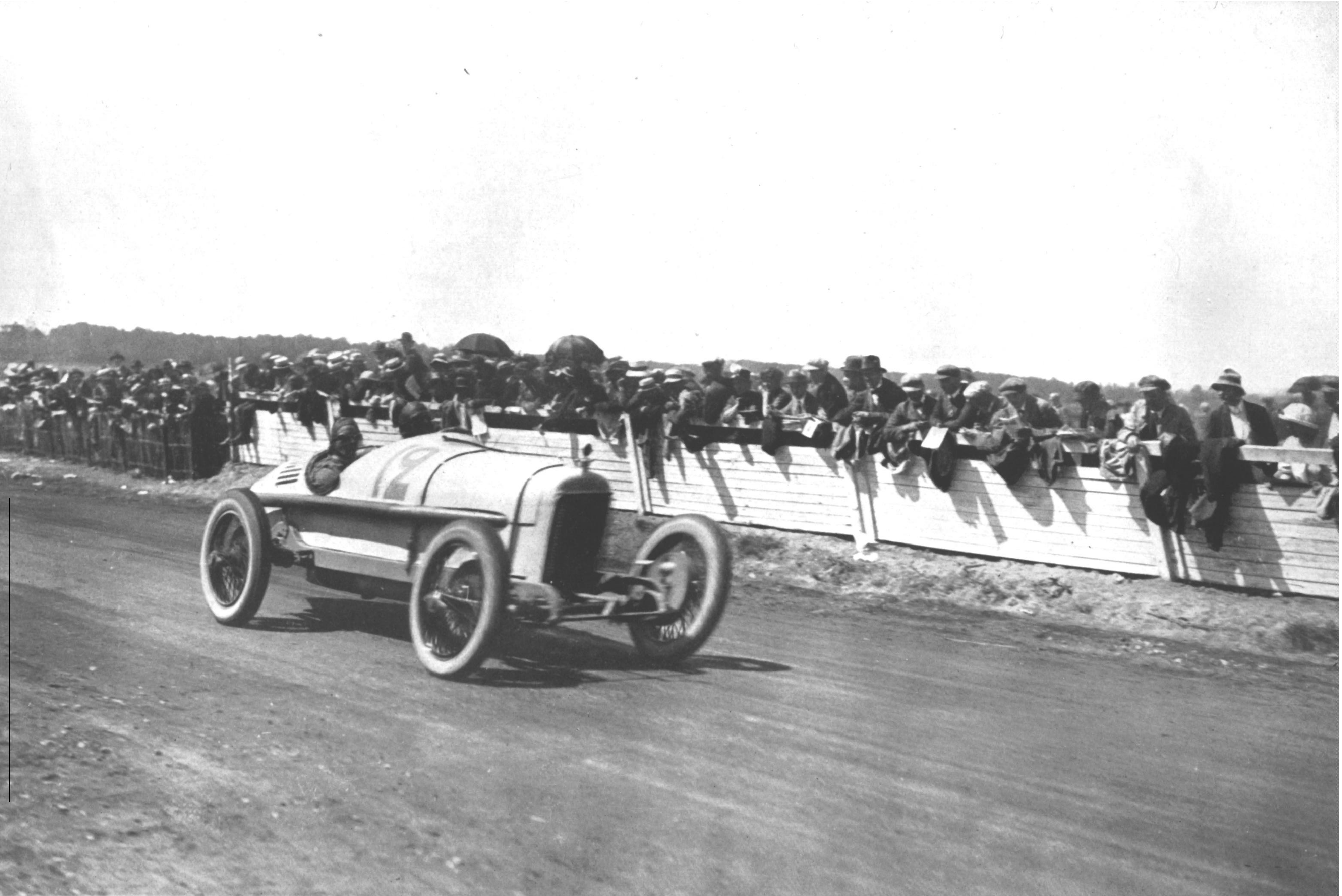


PLATE XXXIV

ROCKY ROADS. — " Even when the dust was laid by oil, calcium, or in the end by tar, it was normal for the surface to break up on the corners during the event, and in some cases on the straight also. This was particularly apparent in the 1921 Grand Prix at Le Mans, in which a number of cars were forced to retire by stones penetrating radiators, sumps and tanks, and one of the American Duesenburg team, Joe Boyer said : ' Hell, boys, this ain't no race, this is a stone-throwing competition'."

Jimmy Murphy on the Le Mans circuit in 1921 when he drove the first eight-cylinder four-wheel-braked car (a Duesenburg) to win a road race.

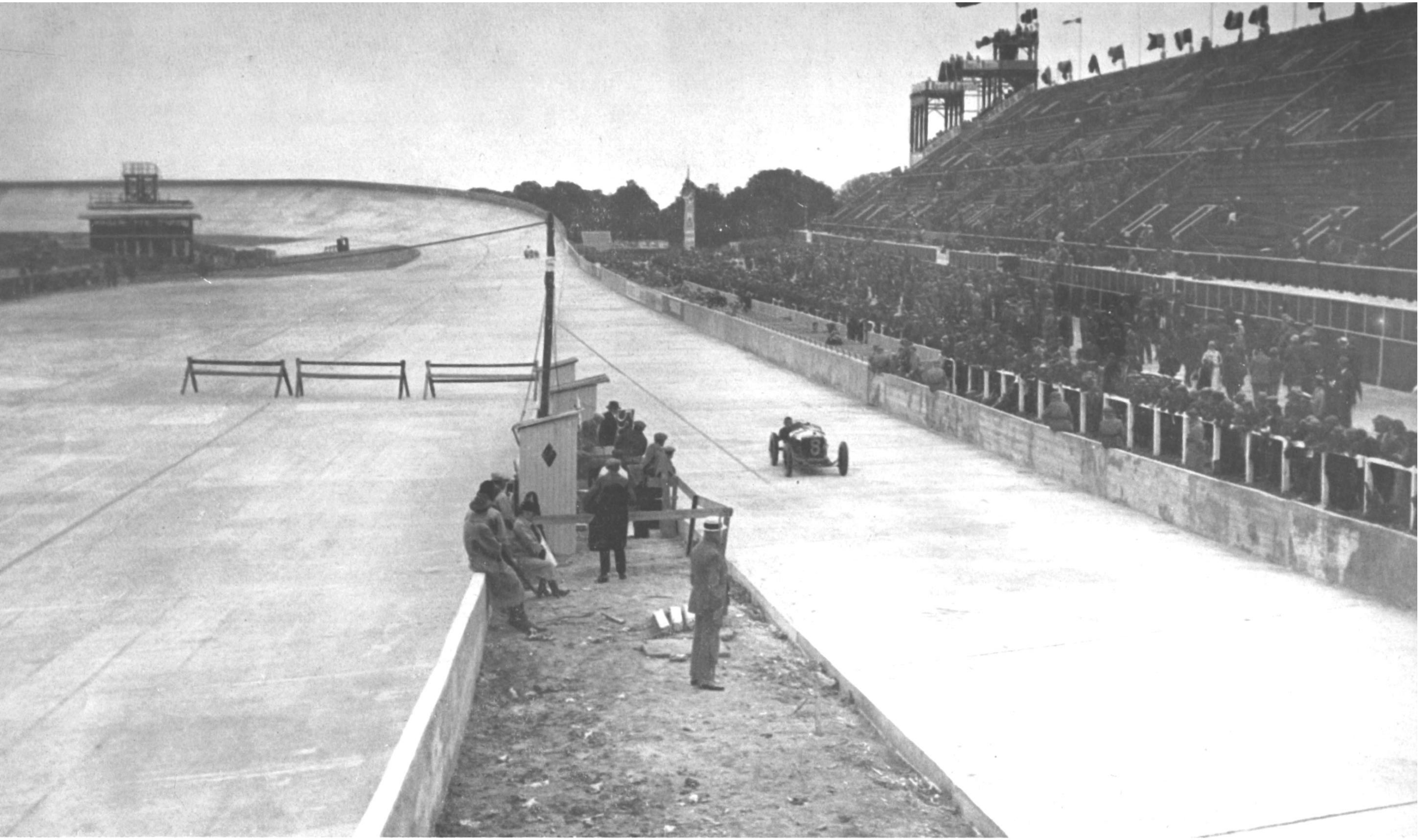


PLATE XXXV

WIDE OPEN SPACES. — " The advantages of these private courses were obvious. The road surface was used only for racing, the grandstands, pits and other installations were permanent, and their capital cost could be amortised over many years, a wide variety of corners, and in some cases gradients, could be introduced, and, perhaps even more important, everybody wishing to see the race had to pay for the privilege. Only the Nürburg Ring, however, turned out to be a business proposition, for both Montlhery and Monza (not to mention the now-forgotten Sitges in Spain and Mirimas near Marseilles) proved to be too perfect and, lacking spectacular appeal, attracted relatively few spectators."

A. Ascari (father of the 1953 World Champion) driving his 2-litre Alfa Romeo past the empty grandstands in the A.C.F. Grand Prix of' 1925. It was in this race that he was killed, on the twentieth lap.

PLATE XXXVI

TOUGH TEST. - " There was a general decline of interest in Grand Prix racing in the late 'twenties, a period in which the eyes of the world were, undoubtedly, focused upon the Targa Florio as being the supreme test of the racing car. On this wild and mountainous circuit, the highly developed cars, like the twelve-cylinder Delage which, with 200 b.h.p., was the most powerful racing car built before 1932, were at a hopeless disadvantage, and for four consecutive years victory was achieved by the lower-powered, but better balanced, Bugattis."

Divo is shown driving the Delage on his first lap in 1926; this team was withdrawn following the crash and death of Count Masetti at the wheel of a sister car.

PLATE XXXVII

ROUND THE HOUSES. –" In the early 'thirties the first round-the-houses race sprang into popularity, this being on the Monte Carlo circuit, of only 1.98 miles, and here again Bugatti was supreme, although challenged with some success by Alfa Romeo. Circuits which limited average speeds to under 50 m.p.h. were, however, so specialised that they could not satisfy the broad demands of Grand Prix racing and some financially viable alternative became a technical necessity."

Varzi is driving a Type 51 Bugatti into third place in !he 1931 Monaco Grand Prix which was won by his Monagesque team mate, Louis Chiron.

PLATE XXXVIII

CONTEMPLATION. - " Looking back, if 1924 bears the label 'Exit the Riding Mechanic', then 1934 could properly carry the directions 'Entry of the Specialists'. A typical example was Dietrich, of Continental Tyres, who would make the most accurate measurements of tread wear and road temperature in order to advise on tyre sections, tyre pressures and patterns of tread."

Dietrich measures the tyre marks of a Mercedes-Benz on the Spa circuit before the 1935 Belgian Grand Prix.

PLATE XXXIX

CELEBRATION. – " It became increasingly important to achieve maximum publicity for the win. For this reason Press relations were based on a lavish budget which made possible not only champagne parties to meet the drivers after victory, but also extremely informative and well-produced 'hand-outs' distributed before the race, and an ample supply of photographs and other souvenirs after it.

Caracciola after winning the Belgian Grand Prix of 1935 on a 4-litre Mercedes-Benz.

PLATE XL

OVER THE TOP. - " Nor is it likely that we shall see in the future cars so difficult, indeed dangerous to drive, as those built in 1936 and 1937. In effect, only two drivers, Caracciola and Rosemeyer, mastered the problems posed by over-steering cars with a laden weight qf 22 cwt., and an engine output of 600 b.h.p., and between them they won fifteen of the seventeen major races of these two years.

Manfred von Brauchitsch goes over the hill at Donington Park in 1937 on the 5.66litre Mercedes-Benz in which he made the fastest lap.

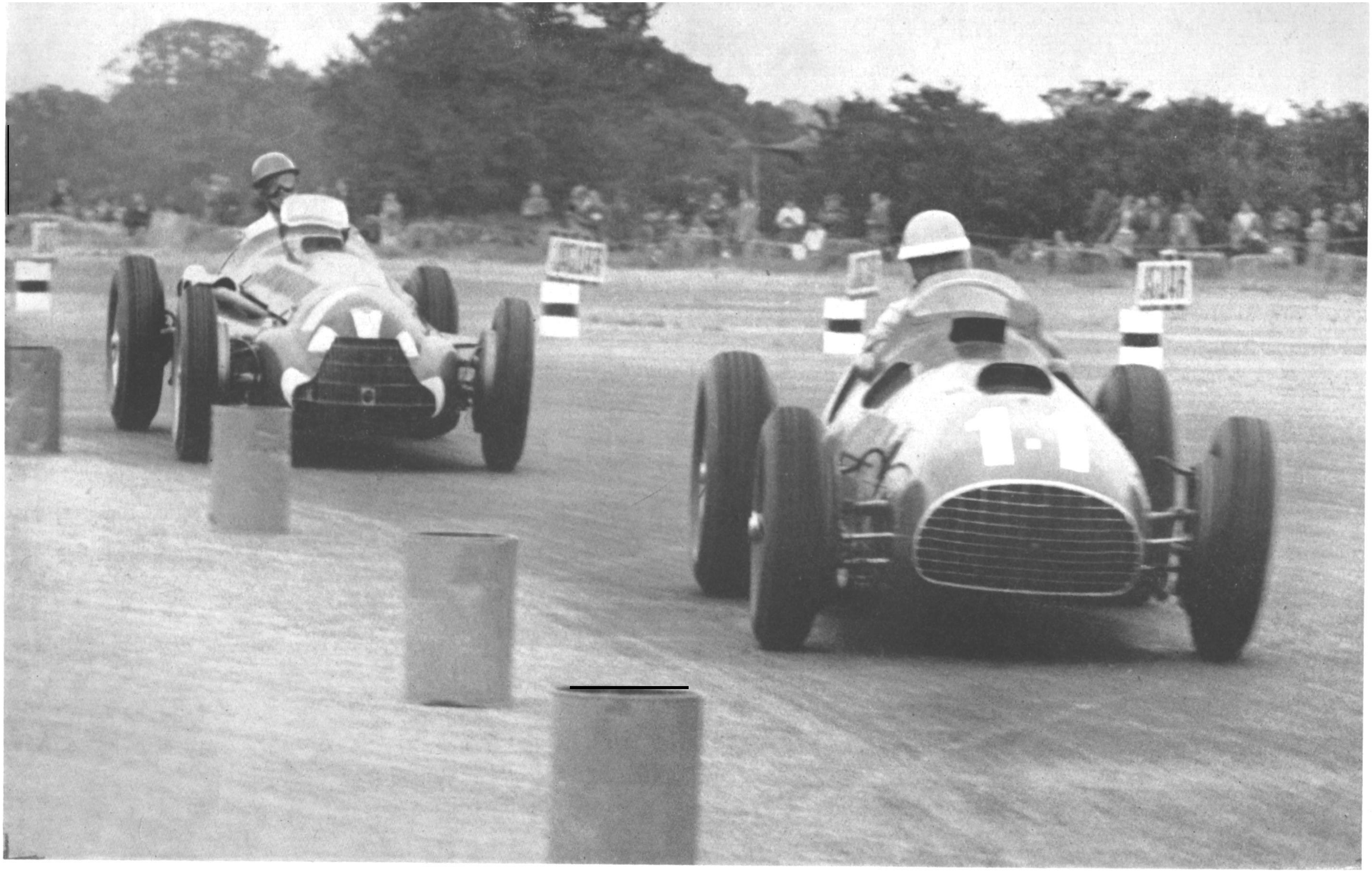


PLATE XLI

SMOOTH STYLISTS. – " Nuvolari pioneered the modern driving position with shoulders and head well back, and arms stretched forward to a rather remote steering wheel.Dr. Farina has popularised this style in the post-war period and we now see the antithesis of the jockey-like crouch as drivers drift their cars on a smooth, predetermined cornering line, leaning right back, and with their eyes, in some cases, raised to heaven."

Here Farina (World Champion, 1951) pursues Ascari (World Champion, 1952-3) in the R.A.C. Grand Prix of 1951. Both drivers have their cars (the 4½-litre Ferrari leading, and the 1½-litre Alfa Romeo) in the four-wheel drift which has done much to raise lap speeds in the post-war period.

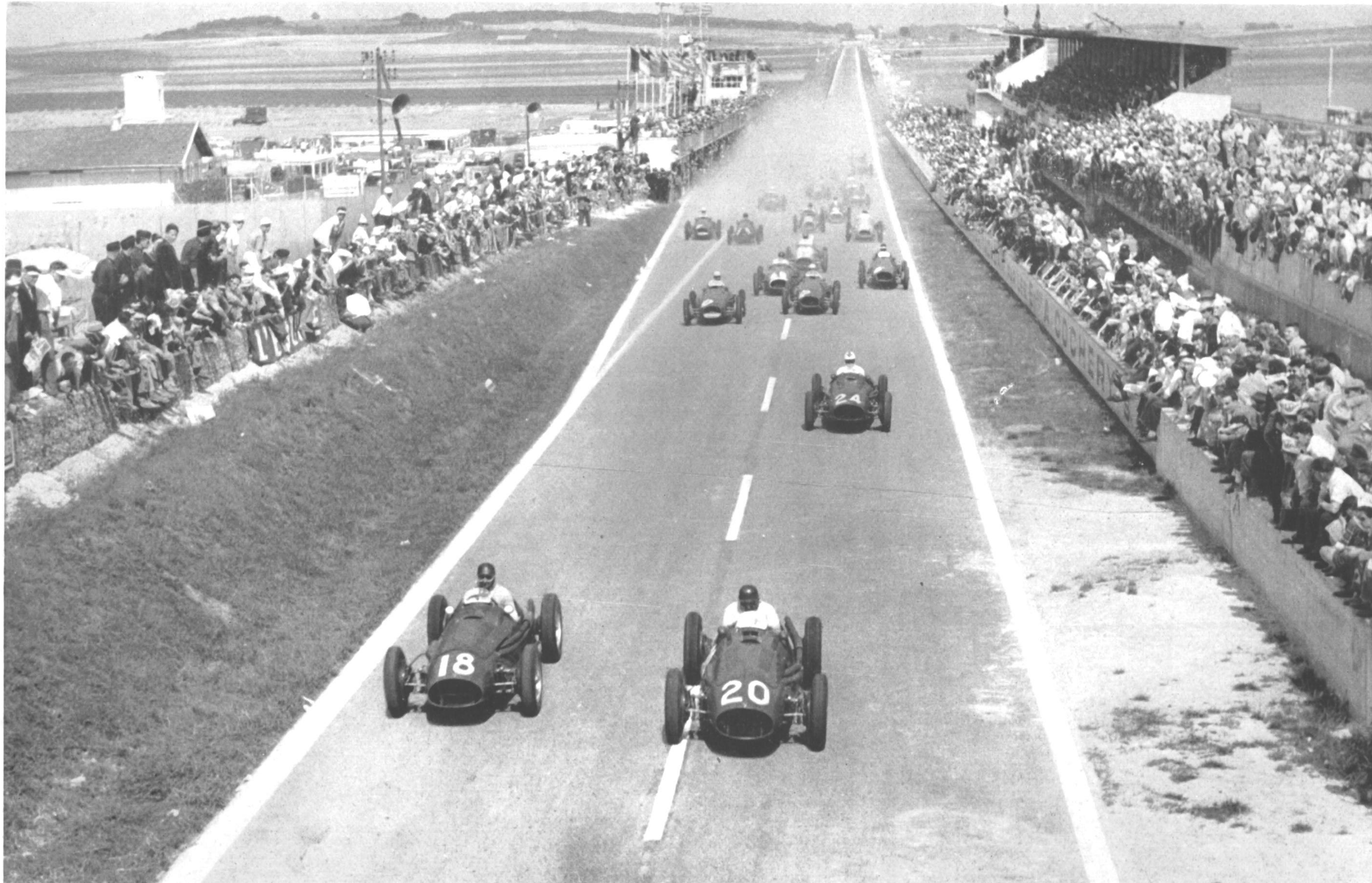


PLATE XLII

THE RIGHT IDEA.--" Permanent success has attended the concept qf a permanent road circuit, at Spa since 1925, at Rheims from 1928, at Berne from 1934 and, since the 1939-45 war, in a number of other localities. Here the public sees real road racing, and at the same time the installations remain standing to serve from year to year."

The public mass to see the 2 litre Formula II cars start in the A.C.F. Grand Prix of 1953 at Rheims. The Maseratis of Gonzales (No. 18) and Fangio (No. 20) get away first.

PLATE XLIII

PRESENT GLORY. – " The skill and the courage qf the real masters such as Ascari, Fangio and Farina has certainly matched, and may well have exceeded, that of any previous drivers, and we can be absolutely sure that we enter a period in which Grand Prix racing cars will travel faster than they have ever done before."

Fangio is driving the W.196 Mercedes-Benz round the Südkehre on the way to victory in the 1954 European Grand Prix staged at the Nürburg Ring.

POSTSCRIPT

THAT persistent, perspicacious, and sometimes obstinate critic, Lord Charnwood, who was actively engaged in the design and construction of racing cars in the mid-'twenties, has often told me that one of the worst features of *The Grand Prix Car* (First Edition) was a tendency to be wise after the event, to judge designs built at differing periods in the light of present-day knowledge and materials, and thus by inference unfairly to criticise earlier engineers.

There may be some justice in his point of view, and it may perhaps be accounted an even more serious weakness that throughout the text as it has previously appeared, racing cars have been reviewed as isolated examples of automobile engineering technique, whereas it may reasonably be contended that they were only tools to achieve certain ends.

If this argument be accepted it becomes necessary to know more about the background to Grand Prix, racing ; why, for example, it has been steadily supported by manufacturers over a period approaching half a century, what was the nature of the circuits over which the races have been run, the type of drivers, and their technique of handling racing cars, the influence of team control and pit work and last, but perhaps not least, the influence of engineering considerations on the aesthetic aspect of the racing car. I have, therefore, resolved briefly to deal with some of these matters in a Postscript and feel that in so doing a change from the impersonal style to a rather more direct narrative may be appropriate in view of the nature of the material. To start, then, with the most important matter, let us consider the financial forces which have supported Grand Prix racing during the past fifty years.

The first three races organised as " Grand Prix " by the Automobile Club de France (in 1906, 1907 and 1908) were all run under different rules, but were all staged with the same purpose. This was to prove to the world that France not only led in the quantity production of motor cars, but also built the fastest and safest cars in the world. The idea of using motor racing as the expression of a politico-industrial idea had originated with the Gordon Bennett series, held between 1900 and 1905, but the continuation of the same theme by the French Club was not a particularly successful enterprise, for after Renault had won in 1906, Fiat and Mercedes were victorious in 1907 and 1908. The temporary collapse of Grand Prix racing in the years 1909, 1910 and 1911 was, however, not entirely due to the natural disappointment of the French organising club. Finance also played a part, and the following statistics, in which I have multiplied the contemporary cost by three to present a fair picture to the modem reader, may be of interest.

In the first Grand Prix of all, the A.C.F. spent the equivalent of £60,000 in preparing and barricading the course, making two by-passes and erecting various structures, including revenue earners, such as the grandstand. Over forty miles of pallisading were put up and the cost of repairing the road surface and attempting to make it dust-proof alone amounted to £6,500 The Club obtained revenues amounting to entry fees of £20,400, a grant from the civic authorities of Le Mans, £12,000, and subsidies from hotel keepers, £3,000. On the morning of the race, therefore, they were out of pocket to the tune of £15,600. It was expected that this would be more than made good by gate money, but the only revenue from this source was seats in the grandstand, and the revenue here was only £4,800, whereas the stand itself cost £7,200 to put up. In round figures, therefore, the first Grand Prix cost the organisers about £10,000 in modern money.

So far as the entrants were concerned, it was, at the time, estimated that a team of three cars with spares, mechanics, etc., would cost about £75,000 in modern money, and with eleven teams the investment of the industry in this event represented roughly three-quarters of a million pounds.

None of the cars would be used for subsequent events, and but a small fraction of this would subsequently be recouped by the sale of cars to private owners.

In view of these figures, it is scarcely surprising that by 1908 both the organisers and the supporters of Grand Prix racing had decided that the benefits obtained were not worth the expenditures involved.

The revival of Grand Prix racing in 1912, and its rise in popularity to the point where it was supported by fourteen manufacturers in 1914, was due to the fact that newly established companies

calculated that the expenditure of even these large sums would give them a really worthwhile return in the event of success. This expectation was based on selling and economic conditions far removed from those of the present day. We must picture a world in which automobile buyers were critical, knowledgeable, and few in number ; indeed, in 1912 the whole output of British industry amounted to only 23,000 vehicles. Despite this, very considerable profits could be earned and, for example, after paying for three cars in the 1913 French Grand Prix, the Sunbeam Motor Co., with a capital of only £120,000, made a net profit of £94,909 2s 3d., the equivalent of, say, £300,000 in modern money. The possibility of making racing pay can be seen from the fact that the Sunbeam profit was trebled between 1910 and 1912 and increased by nearly five times between 1910 and 1913, the very years in which they most prominently engaged in motor sport.

In the post-World War I era, Sunbeam were one of the few companies who continued in the belief that Grand Prix racing was a worthwhile financial investment, and they regularly allocated the equivalent of some £100,000 per annum in modern money to this end. The trend of events was, however, working against both them and their racing rivals and within six years from the re-establishment of Grand Prix racing after World War I, factory support virtually ceased. Between 1921 and 1927 the market for cars in these years had become immensely widened (the British output for 1926 being 198,000 vehicles), whilst the margin of profit shrank to such an extent that the smaller companies found it exceedingly hard to remain in business and impossible to contemplate the kind of expenses involved in Grand Prix racing. Thus, in 1925, the declared profit of the S.T.D. Company which included Sunbeam, amounted to £151,089 19s 6d., but whereas the 1913 £95,000 profit was earned on a capital investment of £120,000, in 1925 the £151,000 was the return on an issued capital of £3,224,408. The profit ratio had thus declined from 15s. 9d. down to 9½d. on every £1 invested. These were typical, not exceptional, conditions in which factory support of Grand Prix racing became an unjustified luxury.

By 1928 economics had transformed racing to the extent that the financial relations of organisers and entrants became reversed. Instead of the competitors providing funds for the organisers, the responsible club now had to subsidise the runners by the inducement of adequate prize money and, in due course, by the substitution of starting money for the traditional entry fee. Bugatti and Maserati, it is true, found it worth while to build special cars for sale to the private entrants, but although there may have been by-products of racing in improved design, prestige of the marque, or national benefit, the point of primary importance was now established. Motor racing had to attract a sufficiently large crowd to make it a profitable proposition, or cease to be. Simultaneously, a multiplication of races became a matter of necessity from the competitors’ point of view.

The cost of a season’s racing, allowing for wear and tear of the car, and the need to replace it, say, every second year, mechanics’ salary, fuel costs, living expenses when actually engaged in racing for, say, three people, amounted to between £5,000 and £8,000 per annum, and even with subsidies from the fuel and tyre companies, a man would have to secure the starting money from at least ten races in the year if the financial burden were not to be crippling.

In these circumstances it was natural that the great national Grands Prix of France, Italy and Spain, etc., should diminish in importance compared with the newer fixtures on the calendar such as Marne, Monaco, Alessandria, Tripoli, Coppa Ciano and Coppa Acerbo.

Between 1928 and 1932 it became common to have between ten and twelve major races each year and, assuming that there was an average attendance of 50,000 persons per race (probably an underestimate), perhaps half a million people each year were witnessing a spectacle that four years before had been observed by barely a fifth of this number. In these circumstances, the Alfa Romeo Co. decided that they would be commercially justified in producing and running a team of specially designed cars, and the introduction of the P.3 model for the Italian Grand Prix of 1932 marks the beginning of a pendulum swing back to the works-prepared team. This move was not made solely upon commercial grounds. In the early ‘thirties, Il Duce saw in motor racing a means of continuing the enthusiasm of the Italian populace for the Fascist regime, and of extending Italian prestige abroad. Alfa Romeo thus became the chosen instrument of a political ideology, and with the rise of the Nazi party to power in Germany, it was not to be expected that the palpable success of Mussolini’s plan would go unnoticed, especially as the Führer was a genuine motor racing enthusiast,

The spirit in which both Auto Union and Mercedes-Benz were urged to engage in Grand Prix motor racing under the 1934 (*et seq.*) 750 kg. Formula may be appreciated from an extract from a German publication, *Mannschaft und Meisterschaft.*

"The Führer has spoken. The 1934 Grand Prix formula shall and must be a measuring stick for German knowledge and German ability. So one thing leads to the other ; first the Führer's over-powering energy, then the formula, a great international problem to which Europe's best devote them-selves, and, finally, action in the design and construction of new racing cars."

The two companies were allowed to offset the costs of racing against rearmament contracts, and from 1934 to 1939 all previous financial bounds were far exceeded. A joint expenditure, amounting in terms of modern money to at least £1 million per annum, was incurred and, with these unprecedented resources, the racing car reached an all-time peak of technical perfection. Simultaneously, opposition to the German cars withered and died, and from a national prestige point of view, the teams were winning somewhat hollow victories just before the struggle was transferred to the Field of Mars. To sum up, when Grand Prix motor racing was for a second time suspended by *force majeure*, it had been through five distinct cycles which may be tabulated thus :

PERIOD A : Years 1906, 1907, 1908

Support mainly based on reasons of national prestige with wins by France, Italy and Germany in successive years.

PERIOD B : Years 1912, 1913, 1914, 1921, 1922, 1923, 1924, 1925, 1926, 1927

Grand Prix racing entered by individual manufacturers as a commercial proposition offering the prospect of increased profits. This phase reached a peak in 1914 and company support dwindled rapidly, to two only in 1927.

PERIOD C : Years 1928, 1929, 1930, 1931

Extension of major races from three or four per annum to ten or twelve per annum, supported mainly by amateur owners prepared to pay for their sport, or professional drivers seeking to earn a living from bonuses, starting and prize money.

PERIOD D : Years 1932, 1933

Fascist support for motor racing with State encouragement for the Alfa Romeo team.

PERIOD E : Years 1934, 1935, 1936, 1937, 1938, 1939

Substantial Nazi support for motor racing with Auto Union and Mercedes-Benz as chosen instruments, leading to overthrow of financial limitations and the co-ordinated use of Grand Prix racing as a means of developing national authority and exports.

Looked at from the above viewpoints, the engineering consequences of Grand Prix racing sink into the background, but a predominant factor in every period has been the presence of a large crowd of spectators. This aspect of a large gate was of particular importance in Period C, when the field for each race was drawn from individuals who were financially dependent upon the organising clubs.

In post-war European motor races the cars have been slightly slower than the pre-war models ; inter-marque competition has, if anything, been less pronounced than in the days of Mercedes-Benz and Auto Union ; and, as Italian cars predominated, there has been no international rivalry. Never-theless, the current popularity of Grand Prix racing is such that it attracts the public in a manner never known before. There are three prime reasons for this. One is the greater spread of technical education and mechanical consciousness through the communities of Western Europe, another, the very low figures of unemployment, with a widespread redistribution of wealth, which has raised the real living standards of most people and last, but by no means least, the development of public address news and race commentaries, so that all the spectators are constantly informed of the pro-gress of events, from the fall of the starter's flag to the display of the chequered flag.

Radio broadcasts and, more recently, television have also played a prominent part in relaying racing car successes to the world at large.

For these reasons success in racing has become far more important; commercially, to the fuel and component manufacturers who supply the owners and builders of racing cars than it has to these people themselves. For example, racing successes have not led to any substantial sale of Ferrari and Maserati cars, and it is arguable whether they have greatly increased the output of Alfa Romeo. Fuel and oil companies have, however, used these cars as vehicles for considerable publicity for their products, and this also applies to such items as tyres, sparking plugs and brake linings. The suppliers have, in fact, found it economical liberally to support successful racing car constructors.

Simultaneously, large crowds have made it possible for race organisers (amongst whom the *Daily Express* has been largely responsible in England) to underwrite big sums for starting and prize money. We can, therefore, add to our summaries :

PERIOD F : Years 1947 to date

Grand Prix racing run as a financially self-supporting public spectacle, with participation from manufacturers selling very few cars to the public and relying for their financial stability upon starting money, prize money and subsidies from component and fuel manufacturers.

The scale of racing at the present time may be gauged from the fact that an outlay of between £40,000 and £50,000 is required before a major Grand Prix is run ; a gross sum that does not differ greatly from the budgets of forty-five years ago. The apportionment is, however, very different. Instead of the organisers receiving entry fees worth £20,000, they will disburse to entrants about £10,000. On the other side of the ledger, in place of under 5,000 spectators contributing less than £5,000, there will be five times that number, and gate receipts will amount to at least 18s. in every £ received.

Nearly all Grand Prix races to-day are run over permanent circuits, and no great outlay is required on them from race to race, and even when problems of alteration or resurfacing have to be considered, the costs are limited by the fact that the total distance round the circuit rarely exceeds five miles, and only in the case of the Nürburg Ring is as much as fourteen miles.

By contrast, the earliest races were between towns, and the first major event was in 1895, when Levassor covered 732 miles on his Panhard (Paris-Bordeaux-Paris), in 48 hours 48 minutes, at an average of 15 m.p.h. As stage coaches could average 12 m.p.h., speeds of this order involved no danger to the public. However, by 1903, performances had increased to the point where Gabriel averaged 65.3 m.p.h. over 342 miles between Paris and Bordeaux, and although the roads were liberally policed, spectators were permitted to stand on the edge of the road over the entire racing distance. There were a number of accidents; in which it is computed that as many as a dozen people were killed, and with the high value set upon human life fifty years ago, the public outcry following was so great that all subsequent major races have been held on closed circuits. The first of these, held in the Ardennes, preceded the Paris-Bordeaux by a year and was fifty-three miles round. The first Grand Prix circuit from the outskirts of Le Mans to St. Calais, across to La Ferte-Bernard and then down the Paris-Le Mans road to the hairpin, was sixty-four miles round, and the Dieppe races of 1907, 1908 and 1912 had a 47.74-mile lap.

For the Amiens Race, in 1913, the circuit of the A.C.F. Grand Prix was reduced to 19.3 miles, at Lyons, in 1914, to 23 miles, and in 1921, at Le Mans, the distance was shortened to 10.6 miles, These shorter laps not only reduced the financial. outlay required in preparing the roads, but also brought the cars far more frequently before the grandstands. On the modern racecourse there is, indeed, a constant procession of vehicles before the spectators, whereas in the earlier races it was common to have a man with a bugle to signal the arrival of one of the competitors.

Putting the matter another way, the modern racing car completes a lap in a little over two minutes at Monza, and in around ten minutes at Nürburg Ring, whereas in the first Grand Prix, on the Sarthe circuit, it took Baras on his Brasier over fifty-two minutes to cover his record lap at an average of 73.3 m.p.h.

The construction of a permanent 6¼-mile circuit within the Royal Park at Monza, in 1922, was followed by the provision of a similar track at Montlhery, outside Paris, where a 7.7-mile lap was opened in 1925, and by the giant concept of the Nürburg Ring, with a 14¼-mile lap, in 1926.

The advantages of these private courses were obvious. The road surface was used only for racing, the grandstands, pits and other installations were permanent, and their capital cost could be amortised over many years, a wide variety of corners, and in some cases gradients, could be introduced, and, perhaps even more important, everybody wishing to see the race had to pay for the privilege. Only the Nürburg Ring, however, turned out to be a business proposition, for both Montlhery and Monza (not to mention the now-forgotten Sitges in Spain and Mirimas near Marseilles) proved to be too perfect and, lacking spectacular appeal, attracted relatively few spectators.

This was a contributary cause in the general decline of interest in Grand Prix racing in the late ‘twenties, a period in which the eyes of the world were, undoubtedly, focused upon the Targa Florio as being the supreme test of the racing car. On this wild and mountainous circuit, the highly-developed cars, like the twelve-cylinder Delage which, with 200 b.h.p., was the most powerful racing car built before 1932, were at a hopeless disadvantage, and for four consecutive years victory was achieved by the lower-powered, but better balanced, Bugattis. In the early ‘thirties the first round-the-houses race sprang into popularity, this being on the Monte Carlo circuit, of only 1.98 miles, and here again Bugatti was supreme, although challenged with some success by Alfa Romeo. Circuits which limited average speeds to under 50 m.p.h. were, however, so specialised that they could not satisfy the broad demands of Grand Prix racing and some financially viable alternative became a technical necessity.

Permanent success has attended the concept of a permanent road circuit, at Spa since 1925, at Rheims from 1928, at Berne from 1934 and, since the 1939-45 war, in a number of other localities. Here the public sees real road racing, and at the same time the installations remain standing to serve from year to year.

Another change which has led to greater attendance at Grand Prix races is to be seen in the choice of day and time. The now universally accepted Sunday race was a comparatively late-comer, the earlier events being mid-week affairs, with the 1913 to 1924 races on Saturdays. Moreover, in 1922 the flag was dropped at 8 a.m., and in the earlier events an even earlier start was made. In 1908, Rene de Knyff, in an interview before the Grand Prix, was kind enough to say, “ Access to the stands will be easy this year. For those who do not wish to be in their seats by 6 a.m., or thereabouts, there will be no difficulty in reaching their places by making a slight detour.”

These very early starts were, in some degree, bound up with the great duration in time of the early races as compared to the modern events. Excluding the two-day races of 1906 and 1912, we find that in 1908 the winner’s time was 6 hours 55 minutes, and although in 1921 this had fallen to 4 hours, by 1925 the winner’s time had increased to 8 hours 54 minutes. In 1934 the French Grand Prix was won in 3 hours 40 minutes, and in 1953 the spectators witnessed a mere sprint, which was over in 2 hours 44 minutes after the start.

The early Grand Prix races differed from the modern event in qualities other than the length of the circuit. The first races were run over untarred roads and the dust clouds were such that it was a commonplace in the town-to-town events that with another car ahead a driver deduced the road ahead from the top of the trees or telegraph poles. Even when the dust was laid by oil, calcium, or in the end by tar, it was normal for the surface to break up on the corners during the event, and in some cases on the straight also. This was particularly apparent in the 1921 Grand Prix at Le Mans, in which a number of cars were forced to retire by stones penetrating radiators, sumps and tanks, and one of the American Duesenburg team, Joe Boyer, said, “ Hell, boys, this ain’t no race, this is a stone-throwing competition.” The winning Duesenburg actually finished with no water in the radiator as a result of an accident from this cause, and even in 1924 the road surface on the corners at Lyons deteriorated very badly.

The roads in the early years were often narrow, as well as rough, and, interviewed in 1908, the winning driver not only remarked upon the fact that after the third lap at Dieppe there were “ ruts, some six inches deep, with sharp cornered granite stones lying at the bottom,” but also that “ over many sections, where the road was comparatively narrow, to pass a car was out of the question.”

As a logical consequence of such road surfaces and narrow section, beaded edge, tyres with, by modern standards, poor quality rubber applied to a canvas foundation, tyre troubles were frequent. With the fixed wheels and rims of pre-1906 it was common to have a team of expert fitters at the

replenishment depots, and in the 1905 Gordon Bennett, the Michelin men could slash off with knives four old covers and tubes, and replace with new in 5 minutes 30 seconds.

From 1906 onwards all the work had to be done by the driver and his riding mechanic, but the labour was reduced, firstly, by the employment of replaceable rims with tyres mounted already upon them and, after the relaxation in 1913 of regulations which earlier forbade their use, by complete spare wheels with tyres.

The changes were made, not as now because of wear on the tread, but through deflation caused either by a burst or a cut from the loose road material. The winner of the 1908 Grand Prix changed a rim, on average, every forty minutes during the race, and Rigal, on his Clement-Bayard (who came in fourth), was even more unfortunate, having to change a tyre on his fixed wheels and rims every twenty minutes.

It was general practice to stop at the replenishment depot every lap and make good the tyres which had been changed during the preceding circuit, and as many as four spares were carried by some of the cars. From all this it will be seen that the riding mechanic's job was no sinecure, and that even supposing the time taken per change were only two or three minutes, the running time of the car would be twenty or thirty minutes less, per race, than the published finishing time.

Against these adverse factors in early racing may be set the comparative absence of corners in relation to the total circuit length. This was particularly marked in the case of the 1906 Grand Prix, for after having covered six miles from the stands, the drivers turned left round the 130 degree bend, and then set off down the straight. Apart from a slight kink in the village of Ardenay, this straight certainly deserved the name, for the cars could be held flat out for the ensuing twenty-one miles ! This was followed by eighteen miles with less than a dozen corners of consequence, and the car was then pointed on an almost direct line back to the start.

Circuits were gradually stiffened in subsequent years, and whereas the 1906 driver could steer his car for as long as a quarter-hour without using the gears or brakes, in a modern Grand Prix race on the Nürburg Ring the driver is confronted with a corner every three seconds and a gear change every fifteen seconds.

These changed circumstances have, in the past fifty years, changed correspondingly the qualities demanded from the driver. Muscular strength and supreme physical endurance was a *sine qua non* in all the earlier races, especially as cars ran over rough roads, were stiffly sprung, and needed considerable strength to turn the steering wheel. Up to the 'thirties it was normal for drivers to crouch over the wheel, an attitude dictated originally by a desire to lessen the wind resistance, and useful in that the body could be used to aid the arm muscles in moving the high-geared steering and effecting quick corrections when the car skidded round a corner.

As maximum and cornering speeds rose to over 150 m.p.h. it became impossible to control the car with about one turn from lock to lock, and up to three turns became common. This lessened the arm effort needed, and Nuvolari pioneered the modem driving position with shoulders and head well back, and arms stretched forward to a rather remote steering wheel. Dr. Farina has popularised this style in the post-war period, and we now see the antithesis of the jockey-like crouch as drivers drift their cars on a smooth, predetermined cornering line, leaning right back, and with their eyes, in some cases, raised to heaven.

With, in most cases, perfectly smooth roads and with, comparatively speaking, softly sprung cars, the physical demands made upon the modem driver are relatively small. In consequence, although the top-flight man is probably in his prime in his late twenties, he can continue in the first rank of racing drivers into his late forties or, in exceptional cases,' early fifties. It may, indeed, be said that the development in design enhances the value of moderation and wisdom in driving and discounts the qualities of courage and virtuosity. It is also statistically true that the most successful racing drivers have been the calm and confident rather than the spectacular, Nazzaro being the supreme example in the early days of motoring, Caracciola between 1934 and 1939, and Alberto Ascari in the post-war period.

It is ironic that Ascari's father should, with Seaman, be one of the six cases of a racing driver of the highest calibre being killed when driving in a race ; it is also somewhat strange that the effective working lives of racing car designers are usually briefer than those of racing car drivers !

Birkigt, Ettore Bugatti, Louis Coatalen, Henri and L. H. Pomeroy, a group who really founded the modern school of racing car design in the period 1910 to 1914, were all aged between twenty-seven and thirty-two at this time and ceased original work in this field by the age of forty-five. Jano was in his early thirties when he developed the P.2 Alfa Romeo, and when Nibel died in November, 1934, after having designed the revolutionary Type W.25 Mercedes-Benz, he was only forty-four. By these standards, Lampredi, of Ferrari, is in his prime at thirty-seven, Eberan von Eberhorst exceptional at fifty-five, and Hodkin, of E.R.A., maintaining tradition by producing original designs when under thirty.

The importance of the Chief Engineer in the design of the racing car has, of course, varied between different companies and at different times. Before 1930 this office was, in many companies, the most important that could be held and it was accordingly occupied by great, and highly-paid, individualists fully conscious of their power and prestige. Since then the trend has been towards design teams, a system which has been worked from the earliest period with great success by Mercedes-Benz, who have, nevertheless, relied upon a few gifted individuals to provide direction and control. As a generalisation, it may be said that we have seen the last of the great designers, defining them in a sociological as well as a technical sense, and in both of these aspects there have also been many changes amongst Grand Prix racing drivers.

For the first ten years, motor racing was supported by gentlemen of means who engaged in a sport mainly for the fun of the thing, although, in some cases, their fortunes were aided as well. The beginning of the Grand Prix period coincided with the rise of the professional paid driver, many of whom, such as Sisz and Lautenschlager, were normally employed by their factories as chief test drivers. Carlo Salamano, of Fiat, for example (winner of the 1923 European Grand Prix), remains to-day as head of the testing section of the Fiat works. Others, such as Lancia and Nazarro made sufficient money by racing to be able to found their own car construction companies, and with the rise of professional skill it is natural that the professional virtuoso should come upon the scene.

Georges Boillot, an employee of Peugeot, made himself the idol of the crowd before the 1914-8 war, and he achieved this position not only by his skill at the wheel, but also by his undoubted gift of capturing the imagination of the public or, as his detractors might say, by playing to the gallery. At any rate, he was the first of many who have become public heroes, and of these Nuvolari was undoubtedly the greatest. Up to 1939 there remained an infusion of well-to-do amateurs able to gain a place in a works team by merit alone, Richard Seaman, Manfred von Brauchitsch, Count Trossi, and more recently Sommer and Dr. Farina, being some of the more prominent to succeed Segrave, Guinness, Maggi and Masetti. In the post-war world, however, it can safely be said that racing drivers find this activity a whole-time job, and for the top flight it has always been one offering great rewards, with some pre-war drivers making perhaps as much as £50,000, in modern values, in a single lucky year.

In vivid contrast to the rewards to a few gifted brave men, the relation between the earlier works drivers and their team managers seems feudal by modern standards. It was recorded, as a special mark of the humanity of Louis Coatalen, when he was *patron* of the Sunbeam team, that when a riding mechanic had been lifted from a car with a deeply-cut forehead, as the result of a stone being thrown up, the injured man was graciously given permission to leave the pit to have his injury attended to.

This was in 1913, and ten years later, improvement in tyres, notably the use of a cord foundation, increases in section and the use of the well-base rim, led most of the Grand Prix starters to discard the spare wheel ; and 1924 saw the last of the riding mechanics. A stop on the circuit now meant that it was hardly worthwhile for the driver to continue in the race, and the regulations covering repairs or replenishment at the pits were steadily relaxed, so that first one, and later three, persons could work on the car, with the driver either remaining in it or seeking a brief refuge in the pit itself.

The exit of the riding mechanic brought about a natural change in the shape of the racing car. There have been five basic fashions in racing car bodywork, and we are about to enter a sixth phase. Early experiments with streamlining effected by knife-edged bonnets, slab-sided tails and radiators slung externally below the front of the frame were disappointing, and up to 1912 most racing cars were merely a chassis with two seats attached and space for a fuel tank and spare wheels

behind. Aesthetically, as well as mechanically, the 1912 Grand Prix at Dieppe was a dividing point, for whereas the big cars, exemplified by Peugeot and Fiat, retained the earlier tradition, the 3-litre models, as typified by Sizaire-Naudin, Sunbeam and Vauxhall, had pleasingly proportionate bodies giving full protection to the occupants, the former pair having long tails, and the last-named a stub tail. Lyons, in 1914, saw the establishment of the long tail fashion with staggered seating for driver and mechanic, and this was continued for the next ten years.

In the first single-seater cars of 1926 and 1927 the driver was offset in a very low car with the seat placed well beneath the propeller shaft line. This theme was varied in the Mercedes-Benz of 1938-9, by placing the driver very low down, but the seat central in the car, the propeller shaft itself being offset sideways, and B.R.M. have followed this arrangement in the post-war period. The rear-engined Auto Unions of 1934-9 were the exceptions which test every rule, and everyone else has followed the example set by the 1932 Alfa Romeos which had single-seater bodies centrally placed above the propeller shaft, the greater frontal area of this arrangement being accepted in exchange for mechanical simplicity. It has become general to place double reduction gears at the end of the propeller shaft so that this component, and the seat, can be lowered by, say, two inches, and in the post-war years that once predominant feature of the racing car, the radiator, has disappeared within a projecting, downward sloping, cowling, expressively described by the Americans as a " drooped snoot."

Looking forward, we know that we stand on the threshold of fully aerodynamic bodies giving enclosure to the wheels and the driver, and although such shapes will pose problems of weight and high speed stability; it can be reckoned that they are the type of the future.

Looking back, if 1924 bears the label " Exit the Riding Mechanic " then 1934 could properly carry the directions " Entry of the Specialists " In that year the organisation of motor racing by the Germans, for the purpose of national propaganda as well as for private publicity, made it possible financially greatly to increase the number of technicians who attended the cars on their courses. A typical example was Dietrich, of Continental Tyres, who would make the most accurate measurements of tread wear and road temperature in order to advise on tyre sections, tyre pressures and patterns of tread, and working with him would be engineers concentrating upon carburetter settings, choice of sparking plugs, brake linings and so on. These all played a prominent part in ensuring victory, and when this had been secured it became increasingly important to achieve maximum publicity for the win. For this reason Press relations were based on a lavish budget which made possible not only champagne parties to meet the drivers after victory, but also extremely informative and well-produced " hand-outs " distributed before the race, and an ample supply of photographs and other souvenirs after it. This was perhaps an isolated phenomenon but the change from the classic concept of one great prize each year, which obtained up to 1914, to a race of major importance every fortnight, twenty years later, has vastly increased the difficulties, as well as the costs, of running any racing team, and taking it from race to race. The Type 59 Bugattis, of 1934, were probably the last Grand Prix cars which could profitably carry a registration number, be used on the road, and driven to a race under their own power, if necessary. Since then all the cars, and a host of impedimenta, have had to be moved around Europe on lorries, and the full equipment of the racing team, then and now, will comprise at least four racing cars and two dozen persons as well as the requisite spare parts. All of this has increased the importance of the racing Team Manager who has become responsible for a most complicated time-table of transport arrangements as well as for team discipline, driver control and expert pit work. The last twenty years have seen enormous progress in the technique of wheel changing and fuel replenishment, and whereas in the 1934 Grand Prix, a typical time by the Mercedes-Benz mechanics was 90 seconds, by 1939 the same operation was undertaken in 30 seconds and this standard of performance has since become normal.

I have been told by Prince Wiacemski that the Mercedes drivers were given a thorough briefing in racing tactics as early as the Grand Prix of 1907. They attended lectures in which they had to learn the recognition points of other makes, and were told the strengths and weaknesses of rival drivers, so that they could play upon them to best advantage.

But team tactics, in the sense of controlling the speed of individual drivers by signals from the pits, were almost impossible when very long circuits were used, with the cars starting at intervals:

In 1914, however, Mercedes were able to control all their cars in a modern manner so as, firstly, to pursue, and then to overtake, Georges Boillot whose Peugeot was in the lead for 230 miles.

The provision of accurate information was complicated before 1922 by the practice of dispatching cars in pairs at intervals, and in the case just mentioned Boillot had left the line five and a half minutes before his pursuer, Lautenschlager. Thus, although he lost the lead on the eighteenth lap, this fact could not be signalled to him until, having completed the nineteenth circuit, he passed the pits on his way to the last round, in which after six and a half hours of desperate struggle he broke up his engine when only fifteen miles from the finish, and was not ashamed to weep.

With massed starts the practice has been extended and refined, although it has been a lesser element in the post-war events than in the immediately pre-war races. With the exception of the years 1949, when Alfa Romeo were absent, and 1951, when they were challenged successfully by Ferrari, the mere entry of a works car of one of these makes has ensured a win in either Formula I or Formula II. The discipline of the Team Manager has, therefore, been concerned only with preventing fruitless struggle within his own team. As a paradox, the entire reverse of this was witnessed in 1953, for in many races the Maserati and Ferrari cars were so evenly matched that it was a case of every driver for himself.

Having by now sketched some of the scantlings which have supported the stage upon which the Grand Prix cars have appeared, I will conclude by discussing the vexed question of " The Golden Age " The myth that Grand Prix racing has enjoyed, in the past, splendours not to be experienced in the present, rests, in part, upon the truth that there have indeed been peak years, notably 1903, 1908, 1914, 1932 and 1937, in the history of motor racing.

But belief in past glories is also a personal and subjective affair. Many men who became enthusiastic about motor racing in their early twenties found their interest waning as they approached their forties. To them, the cars which they saw in a span of, say, fifteen years were the most exciting in the world, and the drivers paragons of skill, courage and chivalry. Apart from this, to those who have a reflective turn of mind, the differing phases of motor racing will have a varied appeal. The antiquarian will obviously be fascinated by the struggles of the pioneers and the extraordinary incidents of the great town-to-town races as depicted by Jarrot.

Each subsequent period has some special virtue of its own. My personal memories of motor racing go back to 1912 (when I was five years of age) and I recollect most vividly the social splendours which determined that even a Hertfordshire hill climb should be accompanied by a marquee with buffet and champagne provided by Lord Rothschild, and attended by men and women of fashion, as well as by the competitors. Moreover, the cars of this time, although deficient in performance by modern standards, loomed so large upon the narrow and somewhat rough roads that they presented a truly awe-inspiring spectacle which may be recovered in part to-day in the race meetings organised by the Vintage Sports-Car Club.

In the mid-'twenties, the element of fashion and personality continued to pervade the motor racing scene, but the smaller cars, of no great speed by modern standards, did not, in themselves, provide an enthralling spectacle and motor racing diminished steadily in popular appeal. Nevertheless, as has been recorded for all time by S. C. H. Davis, who wrote as " Casque " in *The Autocar,* it was a truly entertaining affair to those on the inside.

The 'thirties saw a complete reversal of all that Grand Prix racing had meant in the previous decade. The emphasis was now on mass entertainment, with politics providing both the cash and the moral drive. From a material point of view it is improbable that the world will again see so many motor racing teams, supporting so large an army of mechanics, transporters and specialists.

Nor is it likely that we shall see in the future cars so difficult, indeed dangerous to drive, as those built in 1936 and 1937. In effect, only two drivers, Caracciola and Rosemeyer, mastered the problems posed by over-steering cars with a laden weight of 22 cwt., and an engine output of 600 b.h.p., and between them they won fifteen of the seventeen major races of these two years. With one established, for some ten years, as Germany's most famous racing driver, and the other, a young man recently graduated from motor cycles, this pair exemplified tradition and youth in a manner highly gratifying to the German public, but it must not be thought that national enthusiasms entirely overran the sporting spirit. In the 1938 German Grand Prix, for example; it was Nuvolari who received the loudest and longest cheers as the cars were pushed up to the starting line, and

when Seaman had won we heard the British national anthem before the German was played. Anyone who wishes to recapture the atmosphere of those days should certainly read Monkhouse's *Motor Racing with Mercedes-Benz.*

The post-war cars are less spectacular than the 1934-9 models (and those of 1908-14 for that matter) for, due to their great stability and improvement in driver technique, faster lap speeds have been accompanied by smoother cornering and rarely has the spectator felt that the cars were being driven along the edge of disaster.

Nevertheless, the satanic shriek of the B.R.M.s has equalled the pre-war supercharger scream of the Mercedes-Benz and the skill and courage of the real masters such as Ascari, Fangio and Farina has certainly matched, and may well have exceeded, that of any previous drivers. So, although we are, perhaps, too close to the past five years properly to evaluate their significance in motor racing history, we can be reasonably certain that they will be treated with respect by the historians of the future, and we can be absolutely sure that we enter a period in which Grand Prix racing cars will travel faster than they have ever done before.

APPENDICES

APPENDIX A*

Results of the Major Races, 1947-53

APPENDIX B

Summary of Developments, 1900-53

APPENDIX C

Specification of Successful Cars, 1906-53

APPENDIX D

Maximum and Relative Lap Speeds of the Fastest Cars by Years 1906-53

APPENDIX E

List of Grand Prix Cars by Nationality and Years of Entry
Together with Numbers of Wins in
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** For results of 200 Major Races, 1906-39, see Appendix A, Volume I.*

APPENDIX A
RESULTS OF THE MAJOR RACES, 1947–53

Date	*Course*	*Driver*	*Car*	*Winning Speed m.p.h.*	*Lap Speed (Rec'd*)*
BELGIAN GRAND PRIX					
29/6/47	Spa	J.-P. Wimille	Alfa Romeo	95.28	101.94
9/6/49	,,	L. Rosier	Talbot	96.95	—
		G. Farina	Maserati	—	101.64
18/6/50	(shortened circuit)	J. M. Fangio	Alfa Romeo	110.05	—
		G. Farina	Alfa Romeo	—	115.15*
17/6/51	,, ,,	G. Farina	Alfa Romeo	114.26	—
		J. M. Fangio	Alfa Romeo	—	120.51*
22/6/52	(*See European Grand Prix*)				
21/6/53	,, ,,	A. Ascari	Ferrari	112.47	
		J. M. Fangio	Maserati		117.3 (P)
BRITISH GRAND PRIX					
2/10/48	Silverstone (with chicane)	L. Villoresi	Maserati	72.28	76.82*
14/5/49	,, ,, ,,	E. de Graffenried	Maserati	77.31	—
		B. Bira	Maserati	—	82.82*
13/5/50	(*See European Grand Prix*)				
14/7/51	Silverstone	F. Gonzales	Ferrari	96.11	100.65(P)
		G. Farina	Alfa Romeo	—	99.9*
19/7/52	,,	A. Ascari	Ferrari	90.92	95.79 (P)
18/7/53	,,	A. Ascari	Ferrari	92.97	97.57 (P)
EUROPEAN GRAND PRIX					
4/7/48	Berne	C. Trossi	Alfa Romeo	90.81	—
		J.-P. Wimille	Alfa Romeo	—	95.05
11/9/49	Monza	A. Ascari	Ferrari	105.04	111.14
					112.72 (P)
13/5/50	Silverstone	G. Farina	Alfa Romeo	90.95	94.02*
1/7/51	Rheims	J. M. Fangio	Alfa Romeo	110.97	118.29*
					119.99 (P)
22/6/52	Spa	A. Ascari	Ferrari	103.13	114.03 (P)
FRENCH GRAND PRIX					
21/9/47	Lyons	L. Chiron	Talbot	78.09	—
		A. Ascari,			
		L. Villoresi, and			
		E. de Graffenried	Maseratis	—	82.4*
18/7/48	Rheims	J.-P. Wimille	Alfa Romeo	102.1	112.2 (P)
17/7/49 (Grand Prix de France)	,,	L. Chiron	Talbot	99.98	—
		P. Whitehead	Ferrari	—	105.1
2/7/50	,,	J. M. Fangio	Alfa Romeo	104.83	112.35
					116.2 (P)
1/7/51	(*See European Grand Prix*)				
6/7/52	Rouen	A. Ascari	Ferrari	80.14	84.63 (P)
5/7/53	New Rheims	M. Hawthorn	Ferrari	113.65	
		J. M. Fangio	Maserati		115.91
GERMAN GRAND PRIX					
29/7/51	Nürburg Ring	A. Ascari	Ferrari	83.76	—
		J. M. Fangio	Alfa Romeo	—	85.69

Date	Course	Driver	Car	Winning Speed m.p.h.	Lap Speed (Rec'd*)
GERMAN GRAND PRIX (*cont'd*)					
3/8/52	Nürburg Ring	A. Ascari	Ferrari	82.21	84.4
2/8/53	„	G. Farina A. Ascari	Ferrari Ferrari	83.89	 85.62
ITALIAN GRAND PRIX					
7/9/47	Turin	C. Trossi	Alfa Romeo	70.29	74.16*
5/9/48	„	J.-P. Wimille	Alfa Romeo	70.38	78.61*
11/9/49	(*See European Grand Prix*)				
3/9/50	Monza	G. Farina J. M. Fangio	Alfa Romeo Alfa Romeo	109.67 —	— 117.44*
16/9/51	„	A. Ascari G. Farina	Ferrari Alfa Romeo	115.93 —	— 120.97*
7/9/52	„	A. Ascari	Ferrari	109.8	112.04 (P)
13/9/53	„	J. M. Fangio A. Ascari	Maserati Ferrari	110.69	 114.86 (P)
NETHERLANDS GRAND PRIX					
31/7/49	Zandvoort	L. Villoresi B. Bira	Ferrari Maserati	77.12 —	— 79.49*
23/7/50	„	L. Rosier J. M. Fangio	Talbot Maserati	76.44 —	— 82.5*
22/7/51	„	L. Rosier A. Pilette	Talbot Talbot	78.46	— 82.27
MARNE GRAND PRIX					
6/7/47	Rheims	C. Kautz L. Villoresi	Maserati Maserati	95.8	— 100.99
MONACO GRAND PRIX					
16/5/48	Monte Carlo	G. Farina	Maserati	59.61	62.32
21/5/50	„	J. M. Fangio	Alfa Romeo	61.33	64.09
MONZA GRAND PRIX					
17/10/48	Monza	J.-P. Wimille C. Sanesi	Alfa Romeo Alfa Romeo	109.98 —	— 116.95*
PENYA RHIN GRAND PRIX					
31/10/48	Pedralbes	L. Villoresi	Maserati	89.44	94.16*
29/10/50	„	A. Ascari	Ferrari	93.8	97.7*
28/10/51	(and Spanish Grand Prix)	J. M. Fangio A. Ascari	Alfa Romeo Ferrari	98.76	105.2* 108.1 (P)
RHEIMS GRAND PRIX					
29/6/52	Modified Rheims	J. Behra A. Ascari	Gordini Ferrari	105.33	 110.04 (P)
SWISS GRAND PRIX					
8/6/47	Berne	J.-P. Wimille	Alfa Romeo	95.42	96.85
4/7/48	(*See European Grand Prix*)				
3/7/49	„	A. Ascari G. Farina	Ferrari Maserati	90.76 —	— 95.1
4/6/50	„	G. Farina	Alfa Romeo	92.76	100.68
27/5/51	„	J. M. Fangio	Alfa Romeo	89.05	104.46 (P)
23/8/53	Berne	A. Ascari J. M. Fangio	Ferrari Maserati	97.17 —	— 101.72 (P)

Date	*Conditions*	*Type of Car*	*Technical Notes*	*Leading Makes*
1900-6	Pre-Grand Prix period of Gordon Bennett and other town-to-town races over distances up to 600 miles. 1904 and 1905 Gordon Bennett races run on closed circuits of 300 miles distance.	Cars changed from primitive types with 5-litre, 25 b.h.p. engines to 10-16-litre models developing 90-120 b.h.p. at 1,000-1,400 r.p.m. as used in the Gordon Bennett Races of 1903-5.	General form of the racing car established, together with initial appearance of many subsequent features such as I.F.S. (Bollee) ; inclined o.h.v. (Pipe) ; gate change, honeycomb radiator and overhead camshaft (Mercedes) ; friction shock absorbers (Mors) ; clash type gearbox (Panhard) ; girder type tubular frame and alcohol benzol fuel mixture (Gobron Brillié) ; propeller shaft drive with live axle (Renault), and de Dion type axle.	Richard Brasier, Darracq, Fiat, Mercedes, Mors, Napier, Panhard and Renault.
1906-7	First Grand Prix races organised by Automobile Club de France and run under weight limit of 2,240 lb., 1906 ; consumption limit 9.4 m.p.g., 1907, over 770 and 477 miles respectively. Road surface of water-bound macadam and tarred, with lap lengths of *circa* 50 miles duration and races 5-7 hours each day, with two-day racing in 1906. Competitors despatched singly, at intervals of 90 secs. in 1906, 60 secs. in 1907 on counter-clockwise courses. Pressure refuelling commonly used. First national racing colours in Grand Prix racing in 1907.	Similar to preceding Gordon Bennett models, using four-cylinder short-stroke engines of 12-18 litres capacity, developing between 100 and 120 b.h.p. Engine speed restricted to *circa* 1,200 r.p.m. with mainly short strokes and low tension magnetos. Fixed wooden wheels with limited use of detachable rims and equal division between propeller shaft and chain final drive. Steel channel frames straight in side elevation and plan with low-sided bodies consisting of two high-built seats with cylindrical fuel tank and spare wheels mounted behind them.	Fiat used inclined overhead valves operated by push-rods and Mercedes raced a six-cylinder overhead camshaft engine in 1907. Straight-eight engines were entered in the 1907 Grand Prix by Weigel, Porthos and Dufaux. First use of supercharging by Chadwick with centrifugal supercharger in Great Despair hill-climb (U.S.A.), 1907, and three-stage centrifugal supercharging in 1908.	Clement Bayard, Richard Brasier, De Dietrich, Fiat, Renault and Darracq.
1908	Grand Prix formula restricted piston area to 117 sq. in., equivalent to 155 mm. bore diameter for four-cylinder engines ; 127 mm. diameter for six cylinders. First use of " pits " in front of grandstands.	Four cylinders, short-stroke push rod o.h.v. engines, developing 130-140 b.h.p. at 1,400-1,800 r.p.m. from 12 litres capacity. Frames, transmission systems and bodies on same general lines as 1906-7. Some cars used dropped frames and there was general use of relatively high scuttles and enclosed body sides.	Detachable wire wheels proposed for Napier Grand Prix cars, but banned by A.C.F. General use of detachable rims on fixed wooden wheels. Clement Bayard successfully used overhead camshaft engines and Motobloc initiate central flywheel.	Clement Bayard, Benz, Fiat, Mercedes, Richard Brasier and De Dietrich.
1909-11	Grand Prix racing abandoned for four years. Old-established companies retired from competition work with the exception of Fiat in U.S.A. races and European hill-climbs. Voiturette racing enthusiastically supported by newly formed firms, such as Delage and Peugeot.	Nil.	Independent front wheel suspension revived by Sizaire-Naudin in 1907 on Voiturette racing cars of restricted piston area. Use of stroke-bore ratios of up to 2.5:l piston speeds of 3,000 ft./min. and multiple valves fostered by these regulations. First use of front brakes by Isotta Fraschini in Indianapolis 500 Mile Race of 1910 and Santa Monica (1911).	Nil.
1912	A.C.F. Grand Prix re-established with a two-day race over 955 miles, with no restrictions on weight or engine size. Circuit as employed in 1907-8, but tarred roads produced improved road surfaces.	Struggle between old and new forms, Fiat represented former in race with 14-litre, four-cylinder, short stroke, o.h. camshaft engine with chain drive and fixed wooden wheels with detachable rims. Peugeot initiated new trend with smaller and lighter 7.6-litre long-stroke engine with propeller shaft drive (Hotchkiss system), and detachable wire wheels. The large cars developing 120-140 b.h.p. were challenged by 3-litre, four-cylinder, side-valve Sunbeams and Vauxhalls, developing 65-75 b.h.p. at 3,000 r.p.m. and weighing less than one ton. Sunbeam (third in Grand Prix) used tapering tails based on Brooklands experience.	Peugeot originated the twin overhead camshaft engine with four valves per cylinder and central plug location in a monobloc casting and carried forward their Voiturette experience to show the merits of the long stroke (1.82:l ratio) engine. Sunbeam and Vauxhall successes proved the possibility of engines with pressed steel pistons running at 2,800-3,000 r.p.m. in long-distance racing. All cars had high tension ignition.	Fiat, Peugeot, Sunbeam, Vauxhall.
1913	A.C.F. Grand Prix run under fuel consumption limited to 14 m.p.h. for cars weighing not less than 800 Kg. fitted with square backed bodies. Race run over 556 miles with lap distances reduced to 19.52 miles, resulting in cars being on different laps during end of race. Increasing interest in 3-litre car racing. Change to clockwise courses used for all subsequent Grand Prix events. First Saturday race, continued until 1925.	Grand Prix and 3-litre racing dominated by Peugeot, using four-cylinder long-stroke (2:l); twin camshaft engines developing 90 b.h.p. for the small size and approximately 130 b.h.p. in Grand Prix form. Taper tails on Grand Prix bodies excluded by regulation.	Peugeot initiated two-piece bolted-up crankshaft (running in ball and roller bearings), inserted endwise through a barrel-type crankcase and dry sump lubrication, also used knock-off lock rings for detachable wire wheels Increased employment of built-up pressed steel pistons. Last use of chain drive in racing of Grand Prix status by Mercedes in Sarthe Grand Prix. Mercedes pioneered use of separate forged steel cylinders with welded ports and jackets in same race. Delage used five-speeds and horizontal opposed valves. First appearance of sleeve valves (Mercedes at Indianapolis) and last appearance of side valve engines in Grand Prix racing.	Delage, Peugeot, Sunbeam ; re-entry of Mercedes with privately sponsored team of experimental cars.
1914	4½-litre capacity limit for A.C.F. Grand Prix run over 20 laps of 23.3 mile circuit. Development of team tactics amongst entries received from 14 manufacturers.	General use of long-stroke, four-cylinder engines with four valves per cylinder operated by one or two overhead camshafts. Engine output *circa* 120 b.h.p. at 2,800 r.p.m. with cars weighing approx. 23 cwt. Seat height reduced by double drop frame side rails. Tapering-tail bodies employed by Peugeot.	First use of four-wheel brakes in European racing by Delage, Peugeot, Fiat and Piccard Pictet. First use of combined engine and gearbox units by Fiat and mica-insulated plugs (K.L.G.) fitted in Sunbeams. Delage tried positively closed valves, and Vauxhall pioneered front springs passing through the front axle.	Delage, Mercedes, Peugeot, Sunbeam.

Date	Conditions	Type of Car	Technical Notes	Leading Makes
1915-6-7-9	Racing confined to U.S.A. track events.	1914 Grand Prix cars uniformly successful with the post-war-built Ballot showing superior lap speed in 1919, although using traditional bolster tank body.	First successful use of eight cylinders in line by 4.9-litre Ballots and Duesenbergs (the latter having detachable cylinder heads) and of V.12 engine by Packard, all in 1919 Indianapolis race except Packard, which ran first in 1917 at Sheepshead Bay.	Ballot, Mercedes, Packard, Peugeot.
1920	Engines limited to 3 litres capacity by international formula, but racing restricted to U.S.A.	General use of long-tailed bodies under influence of high speeds attained at Indianapolis.	One out of four starters at Indianapolis had eight-cylinder in-line engines runnmg at approximately 3,500 r.p.m. with an S/B ratio of 1.7:l. First use of light alloy pistons and multi-carburetters in Grand Prix racing.	Ballot, Duesenberg, Monroe.
1921	International racing revived under 3-litre capacity limit. A.C.F. Grand Prix held over 10.6 mile circuit with very loose surface. Pits now abandoned in favour of road-level depots ; pressure or gravity refuelling forbidden, and replaced by cans or churns.	Almost unanimous use of long-stroke, eight-cylinder engines with more than two valves per cylinder, developing 115-120 b.h.p. at 3,500-4,200 r.p.m. Wide use of long-tailed bodies with staggered seating and close under-cowling.	First use in Grand Prix racing of hydraulically operated brakes, high-tension coil ignition, and three overhead valves per cylinder, and three-speed gearbox with central gear lever, all by Duesenberg. First use of mechanical servo brake operation (Ballot and Fiat), and of forged steel cylinders in group, and all-roller bearing crankshaft, both by Fiat in Brescia Grand Prix. First supercharged engine in European racing, the Mercedes using Roots blower in CoppaFlorio. ExperimentsbyRicardowithalcoholblendfuel-RD1,RD2,etc.	Ballot, Duesenberg, Fiat.
1922	International 2-litre limit for Grand Prix racing. First national Grand Prix other than French (Italian) ; world's first artificial road circuit built in Monza Park ; first massed start for A.C.F. (French) Grand Prix at Strasbourg.	Reduction in engine capacity leads to revival of four- and six-cylinder engines, developing 80-90 b.h.p. at 4,500-5,000 r.p.m. fitted into small cars weighing under 15 cwt. Fiat introduced wedge-shaped bodies, but bulk of cars continued with round sections using tapering tails. Last Grand Prix race in which spare wheels were carried on the car. Substantial improvement in road surfaces.	Design dominated by Fiat practice of welded cylinders with two valves per cylinder at 96 degree angle, roller-bearing crankshaft and big-ends, and to!que tube drive. Revival of four- and six-cylinder engines. Vauxhall Inmate one-piece connecting rods and detachable wet cylinder liners in R.A.C. T.T. car.	Fiat.
1923	As 1922.	Similar in general specification to 1922, but many makes reflected the superiority of Fiat in the previous year by producing cars of similar design and/or appearance.	General acceptance of two-valve, two-camshaft engines with roller bearings throughout. First use (by Delage) of V. 12 engine in road racing. First use by Bugatti and Voisin of aerodynamically formed bodies. First victory of supercharged engine in full Grand Prix racing secured by Fiat in European Grand Prix, which also saw first rear-engined racing car with independent rear suspension by swing axle, both featured by Benz cars.	Fiat, Sunbeam.
1924	As 1923.	As 1923, with slight increases in stiffness and weight.	Light alloy wheel and brake drums fitted on Type 35 Bugatti. Designers tended tqrevert to eight-cylinder in-line engines. First use of superchargers aspirating mixture from the carburetter by Duesenberg at Indianapolis (with centrifugal blower) and Sunbeam in French Grand Prix with Roots blower. All Grand Prix status races won by supercharged cars using alcohol-benzol fuel.	Alfa Romeo, Fiat, Sunbeam.
1925	As 1924 ; riding mechanic barred for first time, but mechanic's seat and driving mirror obligatory. A.C.F. (French) Grand Prix run on 7.6 mile lap on artificial road circuit (Montlhery) for first time. Repair and replenishment of car continued to be restricted to driver and one mechanic alone as in all previous Grand Prix races. Belgian Grand Prix added to international calendar. First Sunday race (A.C.F.)	As 1924.	All Grand Prix cars supercharged except Bugatti, who in Targa Florio, scored last win in Grand Prix racing with an unsupercharged car. General increase in power and speed by detail development. Fiat fitted inter-cooler between blower and carburetter.	Alfa Romeo and Delage.
1926	Grand Prix cars limited to 1½ litres capacity with driver only, but mechanic's seat obligatory, and one mechanic only allowed to assist driver. General use of tracks for national Grands Prix.	Eight-cylinder in-line engines with roller bearings offset to left-hand side of car giving very low driving position and frontal area. Successful year by Bugatti, who continued 1925 chassis with modified engine to bring it within the capacity limit.	All Grand Prix cars used supercharging. Predominance of offset single-seater, but first appearance in European road-racing of bodies with single central seats, these being used by Duesenberg and Miller in 1927 Italian Grand Prix, which marks last appearance of U.S.A. cars in European formula race.	Bugatti and Delage.
1927	As 1926, but mechanic's seat no longer obligatory.	As 1926, but Bugatti two-seater type outclassed.		Talbot and Delage.
1928-30	General disregard of internationally agreed formula with races run under *formule libre.* Feeble support for Grand Prix racing by manufacturers leading to entry lists made up of individuals competing as amateurs for sport or individuals for private advertisement or gain. Grand Prix of A.C.F. run as sports car race ; first Sunday race on public road (1929).	Revived use of 2-litre models designed originally for 1922-5 formula. General use of two-seater bodies and chassis specification, making it possible to use cars for sports car events or general road use in addition to racing.	Little development in engine design. Average speeds improved by detail development in suspension and braking systems. First use by European constructor of detachable cylinder head in Grand Prix racing on 2&litre Maserati. Wide use on this car of magnesium alloy castings ; cylinder head made of cast aluminium. Racing car design influenced by lack of works' teams and maintenance, and alternative entry in sports car racing. Roller bearings abandoned except by Bugatti.	Alfa Romeo, Bugatti, Maserati.

Date	*Conditions*	*Type of Car*	*Technical Notes*	*Leading Makes*
1930-3	No restriction on size of engine or car. Two mechanics in addition to driver(s) allowed to assist in repairs and replenishment. Reintroduction of works-sponsored teams and/or drivers. Contemporary with decline in importance of A.C.F. (French) Grand Prix, a great increase in races of Grand Prix status run by national or urban clubs, e.g., German and Czechoslovak Grands Prix and Rome and Monaco races. First starting line-up on practice times (Monaco Grand Prix, 1933). Revival of pressure refuelling.	Unsuccessful experiments with engines of between four and five litres capacity, developing *circa* 300 b.h.p. Decisively successful introduction of cars with single, central, seats placed above propeller shaft.	Reintroduction of designs built purely for racing but designed under the influence of sports car requirements and making use of series production components. Engine size limited to 3 litres with a maximum of *circa* 5,500 r.p.m. and 200 b.h.p. Revival of hydraulic brakes by Maserati and of de Dion axle in racing by Miller at 1931 Indianapolis. Alfa Romeo made first use of light alloy cylinder blocks with inserted dry liners and integral head with valves facing direct on light alloy seats and built twin-engined car with two propeller shafts followed by V shafts connecting to single engine. Last appearance of non-poppet valve engine (Peugeot in 1931 French Grand Prix).	Alfa Romeo, Bugatti, Maserati.
1934	Introduction of international formula limiting weight to 750 Kg. No restriction on size of engine. Four mechanics permitted to assist in repair and replenishment. Increase in number of Grand Prix status races became a permanent feature of the international calendar. Predominance of works' teams.	Initial successes secured by slightly modified 1933 cars ; later events won by German cars developing 300-400 b.h.p., and many novel technical features. All Grand Prix cars except Bugatti used central single-seater bodies and all, with the exception of Auto Union straight-eight engines.	First use of independent suspension for all four wheels on racing cars by Auto Union and Mercedes-Benz. Revival by Auto Unions of rear-engine mounting pioneered by 1923 Benz. First use of sixteen-cylinder V-type engine by Auto Union. Revival by Mercedes-Benz of welded steel cylinder construction with 60 degree four-valve heads and all-roller bearing crankshaft and of five forward speeds by Auto Union. Increases in engine size in German cars up to 3½-4½ litres. First use of torsion bar springs in Grand Prix racing by Auto Union for front suspension system, and of double reduction rear axle to give low propeller shaft height by Bugatti. First use of welded steel frames in the form of round tubes by Auto Union and rectangular box section by Mercedes-Benz. Revival of detachable wet cylinder liners by Auto Union.	Alfa Romeo, Bugatti, Auto Union, Mercedes-Benz.
1935	As 1934. Portable electric starters first used by Auto Union at A.V.U.S. races. Elimination of successful amateur drivers by works-retained professionals.	As 1934, with larger engines and greater power output.	All successful Grand Prix cars used independent front suspension. Last Grand Prix victory by a car fitted with a live rear axle (Alfa Romeo, German Grand Prix). Increase of engine size in German cars up to 5 litres and of engine output up to 400 b.h.p. All Grand Prix cars, except Bugatti, used hydraulic brakes. Torsion bar springs used for front and rear suspension units on Auto Unions. First use of larger diameter rims on rear wheels than on front wheels and Z.F. limited slip differential.	Alfa Romeo, Auto Union, Mercedes-Benz.
1936	As 1935.	As 1935, with engine capacity raised up to 6 litres and power available increased to over 500 b.h.p.	Trend towards high alcohol content fuels (up to over 85 per cent), particularly by Mercedes-Benz. Introduction of two leading shoe brakes.	Auto Union, Alfa Romeo, Mercedes-Benz.
1937	Extension of 1934-6 750 Kg. formula for one year.	General use of engine sizes of between five and six litres with engine outputs of 520-640 b.h.p.	Construction of Type 125 Mercedes-Benz which pioneered thin wall oval tube frame members, wishbone, i.f.s., with open coil springs, and road racing use of de Dion type rear axle. Car performance factors expressed in terms of b.h.p./ton and b.h.p./frontal area, reached an all-time high level. Outstanding reliability of German-built cars. Mercedes-Benz abandoned supply of pressure air from supercharger to carburetters (Vanderbilt Trophy). Development on German cars of Ethelyne-Glycol for cooling, and four leading shoe brakes by Auto Union. Hydraulic shock absorbers first used in Grand Prix racing (Mercedes-Benz).	Auto Union, Mercedes-Benz.
1938	Formula based on sliding scale of weight in relation to capacity : weight leading in effect to 3-litre cars weighing not less than 850 Kg.	Continued use of central single-seater bodies on chassis powered by engines developing 400-450 b.h.p. Marked reduction in height by Mercedes-Benz following upon transmission developments.	Auto Union and Mercedes-Benz both reduced spring rates and used hydraulic shock absorbers. Independent rear suspension abandoned by both of these companies in favour of de Dion type rear axle coupled with torsion bar springs. Mercedes-Benz used propeller shaft inclined and offset in both planes which permitted very low mounting of central seat. Increased r.p.m. and supercharged pressures led to deterioration in specific fuel consumption and the need for much larger fuel tanks despite reduction in engine size and total horsepower. Auto Union pioneered side tank, and Mercedes-Benz scuttle tank filled from main rear tank. Revival of V.12 engine by Auto Union and Mercedes-Benz. Unsuccessful experiment by Auto Union of all-enveloping streamlined road-racing cars in A.C.F. Grand Prix at Rheims. Auto Union and Mercedes-Benz had five-speed gearboxes.	Auto Union, Mercedes-Benz.
1939	As 1938.	As 1938, with engine power increased to 480-500 b.h.p.	Auto Union and Mercedes-Benz developed two-stage supercharging, using Roots blowers in series, and supercharge pressures of up to 2.65 Ata. Mercedes-Benz fitted turbo-finned brake drums and raised maximum possible engine speed to 10,000 r.p.m., with peak power developed at 8,000 r.p.m. Auto Union developed floatless carburetters.	Auto Union, Mercedes-Benz.
1946	Extreme shortage of fuels, tyres and plugs, also general breakdown in international communications. Races run under *formule libre*.	Pre-World War II cars except ex-German teams. Alfa Romeo the only entrant of works teams, with 1½-litre Type 158 models modified to two-stage boost for some entries.	Most races run on short circuits at average speeds of under 70 m.p.h. over distances less than 100 miles.	Alfa Romeo, Maserati.

Date	*Conditions*	*Type of Car*	*Technical Notes*	*Leading Makes*
1947-9	First three years of Formula I limiting engines to 1½ litres S. or 4½ litre U/S.	Competition between 4½-litre principle exemplified by six-cylinder Talbot with push-rod-operated valves, and 1½-litre S. types represented by four-cylinder Maserati with equal bore and eight-cylinder Alfa Romeo with bore : stroke ratio 1.2 : 1. General use of tubular frames ; transverse leaf springs ; swing axle and drivers seated immediately above a central propeller shaft with single-stage reduction gears mounted ahead of bevel box.	Superiority of two-stage blown 1½-litre-engined cars over both the unblown type and twelve-cylinder 1½-litre models with single-stage blowing.	Alfa Romeo, Ferrari, Maserati, Talbot.
1950-I	Revival of competition between works teams as sponsored by Alfa Romeo and Ferrari.	Successful challenge to 1½-litre S. models by 4½-litre twelve-cylinder types with over 90 sq. in. piston area developing over 350 h.p. and weighing less than one ton.	Continued use of transverse leaf springs with general supersession of swing axle by de Dion axle at rear of car. Great attention given to brake developments characterised by improved friction lining and substantial increase in the width of the brake drum. Reduction of rim diameters to 17 or 16 in. in order to lower the unsprung weight. No marked change in other chassis design trends or bodywork. First appearance of sixteen-cylinder 1½-litre S. engine with two-stage centrifugal supercharging ; and first appearance of suspension by air struts in racing (B.R.M.)	Alfa Romeo, Ferrari.
1952-3	Formula I replaced (de facto) by Formula II (2 litre U/S or 0.5 litre (S)) ; inter team rivalry between Ferrari, Maserati and Gordini ; many other names giving large numbers of starters.	2-litre engines with four or five cylinders ; single central seat above propeller shaft ; tanks and tyres suffice for 305 miles without a pit stop.	General use of double o.h.c. with S : B ratio of unity or less ; crank speeds of 7,000-8,000 r.p.m. ; one carburetter per cylinder with inlet and exhaust tracts matched for " Ram " effect ; double ignition ; fuel injection used by Connaught and Cooper-Alta ; dominance of de Dion rear axle ; transverse fins on brake drums ; development of the space type frame ; extended use of aluminium and magnesium-zirconium alloys ; light alloy disc or spoked wheels used by Connaught, Cooper and E.R.A.	Connaught, Ferrari, Gordini and Maserati.

APPENDIX C- SPECIFICATION OF SUCCESSFUL CARS, 1906-39*

To achieve a more complete understanding of the specification of any car the following Notes showing the general type of construction followed should be read in conjunction with the specification tables appearing on the following pages.

ENGINE DETAILS

Crankcases. The only exception to the use of light alloy for crankcase construction was No. 123, which used a one-piece cast-iron cylinder block.

Cylinder Blocks. All engines had detachable cylinder blocks except Nos. 123 and 159 (bore cast with crankcase) and Nos. 151, 153, 156, 162 and 163. which had wet liners spigoted into the crankcase.

The detachable blocks were iron castings with the exceptions of Nos. 118, 124, 126, 128, 129, 130, 132, 137, 138, 150, 157, 158, 160 and 164, which used forged steel cylinder barrels with welded-up ports and water jackets. On Nos. 146, 134, 155, light alloy castings were used with dry liners.

Cylinder Heads. All cylinder heads were formed integral with the cylinder block except on Cars Nos. 123, 141, 142, 144, 147, 149, 151, 153, 156, 159, 162 and 163.

Sparking Plugs. All cars with high tension ignition had one 18 mm. sparking plug per cylinder except Nos. 110 and 112, which had two, and No. 118, which had three, 18 mm. plugs per cylinder.

Ignition. Cars Nos. 101, 102, 103, 104, 105, 106, 107, 108 and 109 had low tension magneto ignition ; Cars Nos. 120, 122 and 123 had high tension coil ignition. All others had high tension magneto ignition.

Induction Systems. All cars running with a manifold pressure of over 1 ata. used continuously engaged Roots blowers except No. 129, which, in the 1923 French Grand Prix only, used the Wittig Vane type blower, and Nos. 130 and 140 which used Roots blowers engaged by a clutch coupled to the throttle linkage. In Nos. 129, 130, 131, 140, 150 and 157 pressure air was fed to the carburetters, in all other cases the carburetter was on the suction side of the blower. Two Roots blowers in series giving two-stage boost were used on Nos. 163 and 164.

Bearings. Ball (or roller) main bearings and white metal big-ends were used by Nos. 113, 114, 115. ll5a, 116, 117, 119, 120 and 121. Lead-bronze main bearings and roller big-ends were used by Nos. 153 and 156. All roller (or ball bearings) were used by Nos. 126, 128, 129, 130, 131, 132, 133, 134, 135, 136, 136a, 137, 138, 139, 143, 148, 150, 155, 157, 158, 160, 162, 163 and 164. All others used plain bearings for the big-ends and main bearings.

Pistons. Cars Nos. 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112 and 118, used cast-iron pistons. Cars Nos. 113, 114, 115, 115a, 116 and 117 used pressed or forged steel pistons. Car No. 120 and all higher numbers used light alloy pistons.

Camshafts. All o.h.v. engines used two overhead camshafts except 109 (push rods) and single o.h. camshafts on Nos. 110, 112, 117, 123, 133, 135, 139, 140, 151, 153 and 156.

Camshaft Drive. Spur gears were used except on certain overhead camshaft models which used bevel gears and a vertical shaft, these being Nos. 112, 118, 123, 130, 133, 139, 140, 151, 153, 156, 162 and 163.

CHASSIS DETAILS

Brakes. All cars subsequent to No. 116 had mechanically operated four-wheel brakes with the following exceptions-No. 118 rear brakes only, No. 119 ran at Indianapolis with rear brakes only, and Nos. 123, 149, 150, 151, 153, 155, 156, 157, 158, 160, 161, 162, 163 and 164, which had hydraulic operation of four-wheel brakes. Mechanically driven servo assistance to the pedal effort was provided on Nos. 121, 124, 126, 128, 129, 132, 134, 136 and 136a. Cars Nos. 150 upwards (except 159) used two leading shoes, except Nos. 156, 162 and 163, which had four leading shoes.

Frames. All cars had riveted U-section frames except No. 150, with welded box construction ; Nos. 151, 153, 156, 162 and 163 with welded circular section tubes ; and Nos. 157, 158, 160 and 164 with welded oval section.

Suspension. Car No. 161 had quarter elliptic rear springs. Cars Nos. 133, 135, 139, 143, 148, 152 and 154 had reverse quarter elliptic rear springs. Cars Nos. 151, 155 and 159 had transverse semi-elliptic rear springs. Cars Nos. 150 and 157 had transverse quarter elliptic rear springs. Cars Nos. 153, 156, 158, 162, 163 and 164 had torsion bar rear springs. Cars Nos. 151, 153, 156, 161, 162 and 163 had torsion bar front springs. Cars Nos. 150, 153, 154, 155, 157, 158, 160, 164 had coil front springs. Car No. 159 had a transverse semi-elliptic front spring. Cars Nos. 157, 160, 162, 163 and 164 had hydraulically damped springs. All other cars had semi-elliptic springs with friction damping.

Wheels. Cars Nos. 100-l 10 inclusive, and No. 112, used fixed wood wheels, all with Michelin detachable rims with the exceptions of Nos. 102 and 103. Cars Nos. 111, 113 and all higher numbers used Rudge-Whitworth detachable wire wheels, except Nos. 133, 139, 143 and 148, which had detachable wheels made from light alloy castings integral with the brake drums.

Rear Axles. Every car used bevel gears for the right-angle drive, but in Nos. 101, 102, 104, 105, 107, 108, 109, 110, 112, the final drive was by side chains, and in Nos. 157, 158, 160 and 164 by spur wheels. All used differential mechanisms with the exception of No. 100, but the Z.F. limited slip differential was fitted to Nos. 156, 157, 158, 160, 162 and 163.

Fuel Tanks. Rear-mounted fuel tanks were universally used except on Nos. 162 and 163, which had side tanks. Nos. 160 and 164 had a saddle-tank in addition to the rear tank.

Tyres. All cars up to No. 121 used beaded-edged tyres. All higher numbers had straight-sided tyres. Provision for carrying spare rims or wheels was made on Cars Nos. 100-121 inclusive, on Nos. 125, 133 and 139, and for Targa Florio race only, on No. 131. Cars Nos. 153-164 inclusive used a larger section tyre on the rear wheels than they did on the front wheels.

* Details of 1947-53 cars are set out on pages 336-7.

APPENDIX C— SPECIFICATION OF SUCCESSFUL CARS, 1906–53

Index No.	*Make*	*Year Built*	*Cylinders No., Bore and Stroke*	*Capacity Litres*	*Piston Area sq. in.*	*H.P.*	*R.P.M.*	*Valves No. and Angle*	*Induction*	*Gears*	*Front Axle*	*Rear Axle*	*Seats*	*Frontal Area sq. ft.*	*Laden Weight cwt.*	*Maximum Speed*
100	Renault	1906	4/166/150	13	134	90	1,200	S	Ata	3	Beam	Torque Arms	2 Par'l.	18	27–28	92 m.p.h.
101	Richard Brasier	1906	4/165/140	12	134	105	1,400	S	,,	3	,,	Dead	,,	17	,,	94 m.p.h.
102	De Dietrich	1906	4/190/160	18.1	175	130	1,100	S	,,	4	,,	,,	,,	19	,,	98 m.p.h.
103	Darracq	1906	4/170/140	12.7	140	120	1,400	S	,,	3	,,	Torque Tube	,,	17	,,	94 m.p.h.
104	Fiat	1907	4/180/160	16.2	158	130	1,600	60° inclined	,,	4	,,	Dead	,,	18	,,	98 m.p.h.
105	De Dietrich	1907	4/180/170	17.3	158	120	1,250	S	,,	4	,,	,,	,,	18	,,	95 m.p.h.
106	Minerva	1907	4/145/120	7.9	102.5	90	2,200	E over 1	,,	3	,,	Torque Arms	,,	18	,,	90 m.p.h.
107	Mercedes	1907	4/175/150	14.4	149	120	1,200	Opposed	,,	4	,,	Dead	,,	19	,,	95 m.p.h.
108	Mercedes	1908	4/155/170	12.8	117	135	1,400	Opposed	,,	4	,,	,,	,,	18	,,	104 m.p.h.
109	Fiat	1908	4/155/160	12	117	100	1,800	60°	,,	4	,,	,,	,,	19	29	101 m.p.h.
110	Fiat	1911	4/130/190	10	83	120	1,650	4 vert.	,,	4	,,	,,	,,	18	33	100 m.p.h.
111	Peugeot	1912	4/110/200	7.6	58.5	130	2,200	4 at 60°	,,	4	,,	Hotchkiss	,,	16	28	100 m.p.h.
112	Fiat	1912	4/150/200	14.1	110	140	1,700	4 vert.	,,	4	,,	Dead	,,	18	31	102 m.p.h.
113	Peugeot	1913	4/100/180	5.6	48.6	115	2,500	4 at 60°	,,	4	,,	Hotchkiss	,,	16	27	108 m.p.h.
114	Delage	1913	4/105/180	6.2	53.8	105	2,300	4 horizontal	,,	5	,,	,,	,,	16	27	100 m.p.h.
115	Peugeot	1913	4/78/156	3	29.4	90	2,900	4 at 60°	,,	4	,,	,,	,,	14.5	21	95 m.p.h.
115A	Sunbeam	1914	4/81/160	3.3	31	92	2,800	Other construc-	tional details as 1913 Peugeot							97 m.p.h.
116	Peugeot	1914	4/92/169	4.5	41.2	112	2,800	4 at 60°	Ata	4	,,	Hotchkiss	2 Staggered	13	26	116 m.p.h.
117	Peugeot	1914	4/75/140	2.5	27.3	80	3,000	4 at 60°	,,	4	,,	,,	2 Par'l.	—	21	92 m.p.h.
118	Mercedes	1914	4/93/165	4.5	42	115	2,800	4 at 60°	,,	4	,,	Torque Tube	,,	13	26½	116 m.p.h.
119	Ballot	1919	8/74/140	4.9	53.2	140	3,000	4 at 60°	,,	4	,,	Hotchkiss	,,	15	28	118 m.p.h.
120	Monroe	1920	4/79/152	3	30.2	98	3,200	4 at 60°	,,	3	,,	,,	2 Staggered	14	—	100 m.p.h.
121	Ballot	1920	8/65/112	3	41	107	3,800	4 at 60°	,,	4	,,	,,	,,	12	23	112 m.p.h.
122	Frontenac	1921		Engine as Duesenberg (123)						Chassis and body as 1920 Monroe (120)				14	—	105 m.p.h.
123	Duesenberg	1921	8/63.5/117	3	39.3	115	4,250	3 at 60°	,,	3	,,	Torque Tube	,,	12	23	114 m.p.h.
124	Fiat	1921	8/65/112	3	41	120	4,400	2 at 90°	,,	4	,,	,,	,,	12	23	118 m.p.h.
125	Sunbeam	1921	8/65/112	3	41	108	4,000	4 at 60°	,,	4	,,	Hotchkiss	2 Par'l.	14	24	108 m.p.h.
126	Fiat	1922	6/65/100	2	30.8	92	5,200	2 at 96°	,,	4	,,	Torque Tube	2 Staggered	12.2	18	105 m.p.h.
127	Miller	1923	8/58.8/89	2	33.6	120	5,000	2 at 90°	,,	3	,,	,,	1 Central	—	—	116 m.p.h.
128	Sunbeam	1923	6/67/94	2	32.9	102	5,000	2 at 96°	,,	3	,,	Hotchkiss	2 Staggered	10.8	18.2	108 m.p.h.
129	Fiat	1923	8/60/87.5	2	35	118	5,600	2 at 96°	1.3 Ata	4	,,	Torque Tube	,,	11	19.5	115 m.p.h.
130	Mercedes	1924	4/70/129	2	24	120	4,500	4 at 60°	1.4 ,,	4	,,	,,	2 Par'l.	12	23	115 m.p.h.
131	Alfa Romeo	1924	8/61/85	2	36.2	165	5,500	2 at 100°	1.7 ,,	4	,,	,,	2 Staggered	11	20	135 m.p.h.
132	Sunbeam	1924	6/67/94	2	32.9	138	5,500	2 at 96°	1.47 ,,	4	,,	,,	,,	10.8	20.7	125 m.p.h.

Index No.	*Make*	*Year Built*	*Cylinders No., Bore and Stroke*	*Capacity Litres*	*Piston Area sq. in.*	*H.P.*	*R.P.M.*	*Valves No. and Angle*	*Induction*	*Gears*	*Front Axle*	*Rear Axle*	*Seats*	*Frontal Area sq. ft.*	*Laden Weight cwt.*	*Maximum Speed*
133	Bugatti	1924	8/60/88	2	35	100	5,000	3 vert.	1.0 Ata	4	Beam	Torque Arm	2 Par'l.	10.8	17.5	112 m.p.h.
134	Delage	1925	12/51.3/80	2	38.7	190	7,000	2 at 100°	1.5 ,,	4	,,	Hotchkiss	2 Staggered	11	21	134 m.p.h.
135	Bugatti	1926	8/52/88	1.5	26.3	110	5,500	3 vert.	1.66 ,,	4	,,	Torque Arm	2 Par'l.	10.8	18	110 m.p.h.
136	Delage	1926	As 136A except exhaust on driver's side ; twin blowers on left side and laden weight only 18.3 cwt.													
136A	Delage	1927	8/55.8/76	1.5	30.5	142	6,500	2 at 100°	1.5 ,,	5	,,	Hotchkiss	1 offset	9.5	19.3	128 m.p.h.
137	Talbot	1926	8/56/75.5	1.5	31	145	6,500	2 at 96°	1.95 ,,	4	,,	Torque Tube	,,	9.5	18	130 m.p.h.
138	Fiat	1927	12/50/63	1.5	36.5	160	6,500	2 at 100°	1.7 ,,	4	,,	,,	,,	9.5	18	135 m.p.h.
139	Bugatti	1926–30	8/60/100	2.3	35	135	5,300	3 vert.	1.66 ,,	4	,,	Torque Arm	2 Par'l.	10.8	18.5	125 m.p.h.
140	Mercedes-Benz	1928	6/104/150	7.6	70	300	3,500	2 vert.	1.5 ,,	4	,,	Torque Tube	,,	15	32	140 m.p.h.
141	Maserati	1929	16/67/82	4	75	260	5,500	2 at 90°	1.5 ,,	4	,,	,,	1 offset	11.5	23	155 m.p.h.
142	Maserati	1929–31	8/64/98	2.5	41	175	6,000	2 at 90°	1.6 ,,	4	,,	,,	,,	10.5	19	136 m.p.h.
143	Bugatti	1931	8/60/100	2.3	35	160	5,500	2 at 90°	1.66 ,,	4	,,	Torque Arm	2 Par'l.	10.8	18.5	134 m.p.h.
144	Alfa Romeo	1931	8/65/88	2.3	41	160	5,400	2 at 100°	1.66 ,,	4	,,	Torque Tube	1 offset	12	20	130 m.p.h.
145	Alfa Romeo	1931	12/65/88	3.5	61.5	200	5,000	2 at 100°	1.6 ,,	4	,,	2 Torque Tubes and bevels	1 central	10.5	23	140 m.p.h.
146	Alfa Romeo	1932	8/65/100	2.65	41	190	5,400	2 at 100°	1.6 ,,	4	,,	,, in Vee	,,	10.25	18.2	140 m.p.h.
146A	Alfa Romeo	1934	8/69/100	2.9	46.5	210	5,400	2 at 100°	1.6 ,,	4	,,	,, ,,	,,	11	18.7	145 m.p.h.
147	Maserati	1932	8/67/94	2.8	43.6	As No. 142										
148	Bugatti	1931	8/86/107	4.9	72	300	4,400	2 at 90°	1.6 ,,	3	,,	Torque Arms	2 Par'l.	13	22	145 m.p.h.
149	Maserati	1933	8/69/100	2.9	46.5	205	5,500	2 at 90°	1.66 ,,	4	,,	Torque Tube	1 offset	10.5	19	145 m.p.h.
150	Mercedes-Benz	1934–5	8/82/94.5	4	65	430	5,800	4 at 60°	1.66 ,,	4	Wishbone	Swing Axle	1 central	11.8	20	175 m.p.h.
151	Auto Union	1934	16/68/75	4.4	90	295	4,500	2 at 90°	1.6 ,,	5	Trailing Arms	,,	,,	10.8	21.5	165 m.p.h.
152	Bugatti	1934	8/73/100	3.3	52	240	5,400	2 at 90°	1.6 ,,	4	Beam	Torque Arms	1 offset	11	19	150 m.p.h.
153	Auto Union	1935	16/72.5/75	4.95	102.5	375	4,800	2 at 90°	1.66 ,,	5	Trailing Arms	Swing Axle	1 central	10.8	21.5	180 m.p.h.
154	Alfa Romeo	1935	8/72/100	3.2	50.2	265	5,400	2 at 100°	1.66 ,,	3	Dubonnet	2 Torque Tubes	,,	10.25	19	145 m.p.h.
155	Alfa Romeo	1935	8/77/100	3.8	51.5	305	5,400	2 at 100°	1.66 ,,	3	Wishbones	Swing Axle	,,	11.5	20	150 m.p.h.
156	Auto Union	1936	16/75/85	6	109.5	520	5,000	2 at 90°	1.87 ,,	5	Trailing Arms	,,	,,	10.8	22.4	185 m.p.h.
157	Mercedes-Benz	1936	8/86/102	4.74	72	494	5,800	4 at 60°	1.9 ,,	4	Wishbones	,,	,,	12	20	180 m.p.h.
158	Mercedes-Benz	1937	8/94/102	5.66	86	646	5,800	4 at 60°	1.8 ,,	4	,,	de Dion	,,	12.5	21.8	195 m.p.h.
159	Delahaye	1938	12/75/85	4.5	82	220	5,500	2 at 90°	0.0 ,,	4	Leaf and Wishbone	,,	1 offset	14	23	140 m.p.h.
160	Mercedes-Benz	1938	12/67/70	3	65.5	468	7,800	4 at 60°	2.2 ,,	5	Wishbones	,,	1 central	12.5	23.5	180 m.p.h.
161	Maserati	1938	8/78/78	3	59.5	420	7,000	4 at 90°	2 ,,	4	,,	Torque Tube	,,	12	22	170 m.p.h.
162	Auto Union	1938	12/65/75	3	61.5	420	7,000	2 at 90°	1.9 ,,	5	Trailing Arms	de Dion	,,	11.5	23.5	180 m.p.h.
163	Auto Union	1939	12/65/75	3	61.5	485	7,000	2 at 90°	2.6 ,,	5	,,	,,	,,	11.8	24	195 m.p.h.
164	Mercedes-Benz	1939	12/67/70	3	65.5	483	7,800	4 at 60°	2.65 ,,	5	Wishbones	,,	,,	12.5	24	195 m.p.h.

Index No.	*Make*	*Year Built*	*Cylinders No., Bore and Stroke*	*Capacity Litres*	*Piston Area sq. in.*	*H.P.*	*R.P.M.*	*Valves No. and Angle*	*Induction*	*Gears*	*Front Axle*	*Rear Axle*	*Seats*	*Frontal Area sq. ft.*	*Laden Weight cwt.*	*Maximum Speed*
165	Alfa Romeo	1947	8/58/70	1.5	32.8	254	7,800	2 at 90°	2.2	4	Trailing Arms	Swing Axle	1 Central	11.5	19½	160 m.p.h.
166	,, ,,	1950	8/58/70	1.5	32.8	335	8,000	2 at 90°	2.7	4	,,	,,	,,	11.5	20½	175 m.p.h.
167	,, ,,	1951	8/58/70	1.5	32.8	380	9,000	2 at 90°	3.0	4	,,	de Dion	,,	11.5	21½	195 m.p.h.
168	Ferrari	1949	12/55/52.5	1.5	42.2	300	7,500	2 at 60°	2.4	5	Wishbones	Swing Axle	,,	12.0	17	170 m.p.h.
169	,,	1951	12/80/74.5	4.5	93.6	380	7,500	2 at 60°	1.0	4	,,	de Dion	,,	12.5	20½	185 m.p.h.
170	,,	1952	4/90/78	2.0	39.5	180	7,500	2 at 90°	1.0	4	,,	,,	,,	12.0	16	155 m.p.h.
171	B.R.M.	1953	16/49.5/48.3	1.5	47.8	525	10,500	2 at 90°	5.65	5	Trailing Arms	de Dion	,,	10.0	20	195 m.p.h.
172	Maserati	1953	6/75/75	2.0	41.1	190	8,000	2 at 90°	1.0	4	Wishbones	Torque Arms	,,	11.5	16	150 m.p.h.

In order to segregate the detail construction of the post-war cars from the pre-war models the supplementary information in regard to the latter set out on pages 330-l is here reproduced in respect of the principal cars of Formula I and Formula II.

ENGINE DETAILS

Crankcases. All the above cars used light alloy crankcases, Alfa Romeo and Maserati being split on the centre line of the crankshaft and Ferrari and B.R.M. beneath the centre line.

Cylinder Blocks. Alfa Romeo used a detachable light-alloy cylinder block with inserted dry liners ; Ferrari wet liners screwed into the combustion chambers ; B.R.M. detachable flanged wet liners ; and Maserati dry liners pressed into the upper half of the crankcase.

Cylinder Heads. B.R.M. and Maserati used detachable cylinder heads ; the Ferrari cylinder head was detached with liner, and Alfa Romeo integral with the block casting.

Sparking Plugs. All the cars used 14 mm. sparking plugs, numbers 169, 170 and 172 having two plugs per cylinder.

Ignition. B.R.M. used coil ignition, all others magneto ignition.

Induction Systems. Alfa Romeo had two-stage supercharging with Roots blowers in series, and B.R.M. two-stage supercharging with centrifugal compressors. Ferrari and Maserati were unsupercharged, cars numbers 169, 170 and 172 having individual jet and choke assemblies for each cylinder.

Bearings. Alfa Romeo used ball and roller bearings throughout ; the other cars Vandervell three-layer plain bearings.

Pistons. Aluminium alloy.

Camshafts. Two overhead camshafts, except numbers 168 and 169 which had a single overhead camshaft with rockers.

Camshaft Drive. Spur gears, except for numbers 168 and 169 which had chain drive.

CHASSIS DETAILS

Brakes. B.R.M. used disc brakes with hydraulic servo assistance ; all others hydraulically operated, two leading shoe, brakes.

Frames. Alfa Romeo used oval tube frame ; B.R.M. spaced round tubes ; Ferrari and Maserati tubes with triangulated reinforcement.

Suspension. B.R.M. had Lockheed air struts ; Maserati coil front, and quarter-elliptic rear, springs ; Alfa Romeo and Ferrari, transverse leaf springs fore and aft.

Wheels. All cars used detachable wire wheels.

Rear Axle. Alfa Romeo and Ferrari had a central propeller shaft driving a gearbox mounted below the axle centre final drive by spur wheels and a limited slip differential. Maserati had a reduction gear ahead of the bevel gear in the live axle, and B.R.M. a transversely mounted, five-speed, gearbox with offset propeller shaft driving the halfshafts through spur wheels.

Fuel Tanks. All cars had rear-mounted fuel tanks, numbers 167 and 171 having also scuttle or cockpit mounted tanks.

Tyres. All cars used larger section tyres on the back wheels than on the front wheels.

APPENDIX D

MAXIMUM AND RELATIVE LAP SPEEDS OF FASTEST CARS

Year	*Fastest Car*	*Max. Speed m.p.h.*	*Relative Lap Speed*
1906	Renault	**92**	100
1907	De Dietrich	**98**	102
1908	Mercedes	104	105.5
1912	Fiat	102	108
1913	Peugeot	108	109
1914	Mercedes	116	112
1619	Ballot	118	118.5
1920	Ballot	112	115
1921	Duesenberg	114	116
1922	Fiat	105	111
1923	Fiat	115	116
1924	Sunbeam	125	121
1925	Delage	134	127.5
1927	Delage	128	129
1928	Bugatti	130	127
1929	Alfa Romeo	138	130
1931	Maserati	136	135.5
1932	Alfa Romeo	140	140
1934	Auto Union	165	150
1935	Mercedes-Benz	175	153
1936	Auto Union	185	158
1937	Mercedes-Benz	195	163.4
1938	Mercedes-Benz	180	160
1939	Mercedes-Benz	195	165
1947	Type 158 Alfa Romeo single-stage ..	160	150
1948	Type 158 Alfa Romeo two-stage ..	170	155.7
1949	1.5-litre Ferrari two-stage	165	154
1950	1.5-litre Alfa Romeo two-stage Type 158/159	185	158.4
1951	Type 159/159A Alfa Romeo	195	164.4
1951	4.5-litre U/S Ferrari	185	163.2
1952	Ferrari 2-litre	155	155
1953	Maserati 2-litre	160	158.3

LIST OF GRAND PRIX CARS BY NATIONALITY AND YEARS OF ENTRY, TOGETHER WITH NUMBER OF WINS IN MAJOR EUROPEAN ROAD RACES, 1906-53

FRENCH (59)

Alda	1914	Motobloc	1907-8
Ballot (1)	1921-2	Panhard	1906-8
Bayard, Clement	1906-8	Peugeot (5)	19124
Bugatti (33)	1922-38	Porthos	1907-8
Corre	1907	Renault (1)	1906-8
Darracq (nil) and Lago-Talbot (5)	1906-51	Richard Brasier	1906-8
De Dietrich (1)	1906-12	Rolland Pilain	1912-23
Delage (8)	1913-27	S.E.F.A.C.	1938
Delahaye (2)	1938-9	Schmid	1924
Gobron-Brillié	1906-7	Talbot (2)	1926-7
Gordini (1)	1947-53	Talbot-Darracq	1921
Hotchkiss	1906	Th. Schneider	19134
Mathis	1913-21	Voisin	1923
Mors	1908	Vulpes	1906

ITALIAN (102)

Aquila Italiana	1914	Fiat (8)	1906-25
Alfa Romeo (58)	1924-51	Itala	1906-14
Dufaux	1907	Maserati (15)	1929-53
Ferrari (21)	1949-53	Nazzaro	1914

BRITISH (4)

Alta	1948-53	Cooper	1952-3
Aston Martin	1922	Halford	1927
Austin	1908	H.W.M.	1952-3
B.R.M.	1950-1	Sunbeam (4)	1913-25
Connaught	1952-3	Vauxhall	1914
Weigel	1907-8		

AMERICAN (1)

Christie	1907	Miller	1924
Duesenberg (1)	1921	Thomas	1908

GERMAN (57)

Auto Union (19)	1934-9	Mercedes (4)	1906-24
Benz	1908	Mercedes-Benz (34)	1926-39
Opel	1908-14		

BELGIAN (1)

Excelsior	1912-3	Minerva (1)	1907
Germain	1907-8	Nagant	1914

SWISS (Nil)

Piccard Pictet	1914

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